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THE OHIO RIVER BASIN
ENERGY FACILITY SITING MODEL
Volume I

Methodology

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16. ABSTRACT

This report was prepared as part of the Ohio River Basin Energy Study (ORBES), a multidisciplinary policy research program supported by the Environmental Protection Agency. The siting model developed for ORBES is specifically designed for regional policy analysis. The region includes 423 counties in an area that consists of all of Kentucky and substantial portions of Illinois, Indiana, Ohio, Pennsylvania, and West Virginia.

Policies that affect the siting of generating units indirectly include projections of future electricity production and fuel type and technologies to meet demand. Policies that affect such siting indirectly include the exclusionary requirements of technology to regulations and preferences for one type of siting (e.g., dispersed siting or power parks) over another. Both types are incorporated in the ORBES scenarios. Several important characteristics are included in the siting model: (1) the systematic analysis of different sets of policies that affect siting patterns directly or indirectly; (2) announced utility plans for capacity additions in the near term (1976-85); and (3) sites are defined and evaluated with respect to regional issues, resources, and values. The model is limited to base-loaded steam generating units that use conventional coal and nuclear fuels. A companion volume contains detailed lists of on-line dates and county-level sites for each ORBES scenario.

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FOREWORD

The Ohio River Basin Energy Study (ORBES) is an interdisciplinary, multi-university inquiry into the environmental, economic, and social impacts of energy facility development in a major portion of the Ohio River Basin. The study was initiated by the U.S. Environmental Protection Agency in 1976 in response to a directive from the U.S. Senate Appropriations Committee.

Most of the ORBES research was conducted by a group of faculty members at the University of Illinois, Indiana University, the University of Kentucky, the University of Louisville, The Ohio State University, the University of Pittsburgh, Purdue University, and West Virginia University. In a few instances, the necessary expertise was found at other universities or independent research organizations.

This report is one of a series produced in support of the overall ORBES assessment. For a summary of the entire study, see Ohio River Basin Energy Study (ORBES): Main Report, by the ORBES Core Team, also being published by the U.S. Environmental Protection Agency.

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During Phase II of the Ohio River Basin Energy Study (ORBES), a Siting Group, which I chaired, and which was composed of members of the ORBES Core Team and Advisory Committee, met regularly to define the siting issues, develop the model and translate the energy development scenarios into geographical patterns of future electrical generating capacity. The Core Team members were: Robert E. Bailey and Steven I. Gordon, the Ohio State University; and J. C. Randolph, Indiana University. Bailey was responsible for the air quality component of the siting model; Randolph was responsible for the land use and ecological systems component. Advisory Committee members who participated were: Sy Ali, Public Service Indiana; John Barcalow, Illinois Power Company; Dana E. Limes, Columbus and Southern Ohio Electric Company; Owen A. Lentz, Executive Director, ECAR; and Charles Tillotson, Switzerland County, Indiana.

Steven D. Jansen, University of Illinois at Chicago Circle, and W. W. Jones, Indiana Univeristy, made significant contributions to the work of the Siting Group. Jansen developed procedures for defining the number of generating unit additions for each scenario, and scheduling their on-line dates. Jones was responsible for expanding the model's capacity for land use and ecological systems analysis. Larry Wong, Indiana University, programmed the site suitability component of the model and did the runs for each scenario.

The maps and other graphic materials were produced by the Chicago Area Geographical Information Study (CAGIS) and the Cartographic Laboratory, Department of Geography, University of Illinois at Chicago Circle. Raymond Brod, Eric D. Heckman, Ruth Laski and David Merrill were involved. Steven D. Jansen coordinated the cartographic work.

Ms. Claudette Eldridge, University of Illinois at Chicago Circle, organized and produced this report.

I deeply appreciate the continued dedication, interest and skills of each person involved in the work of the Siting Group.

Gary L. Fowler
University of Illinois at Chicago Circle
November, 1980

SECTION 1

INTRODUCTION

The purpose of power plant siting models in regional technology assessments of energy development is to translate energy-related policies into a geographical pattern of impacts that can be assessed and evaluated. Given an aggregate level of future energy demand, or production, from which a specific number and type of generating unit additions can be determined, the additions must be distributed within a region in a consistent manner that is explicitly related to other scenario elements. Candidate sites, usually counties, are defined by exclusionary criteria and ranked according to their suitability as future sites for electrical generating units. Siting patterns may vary by scenario and, at county scale, are highly dependent on assumptions about energy technologies, resource requirements and environmental policy.

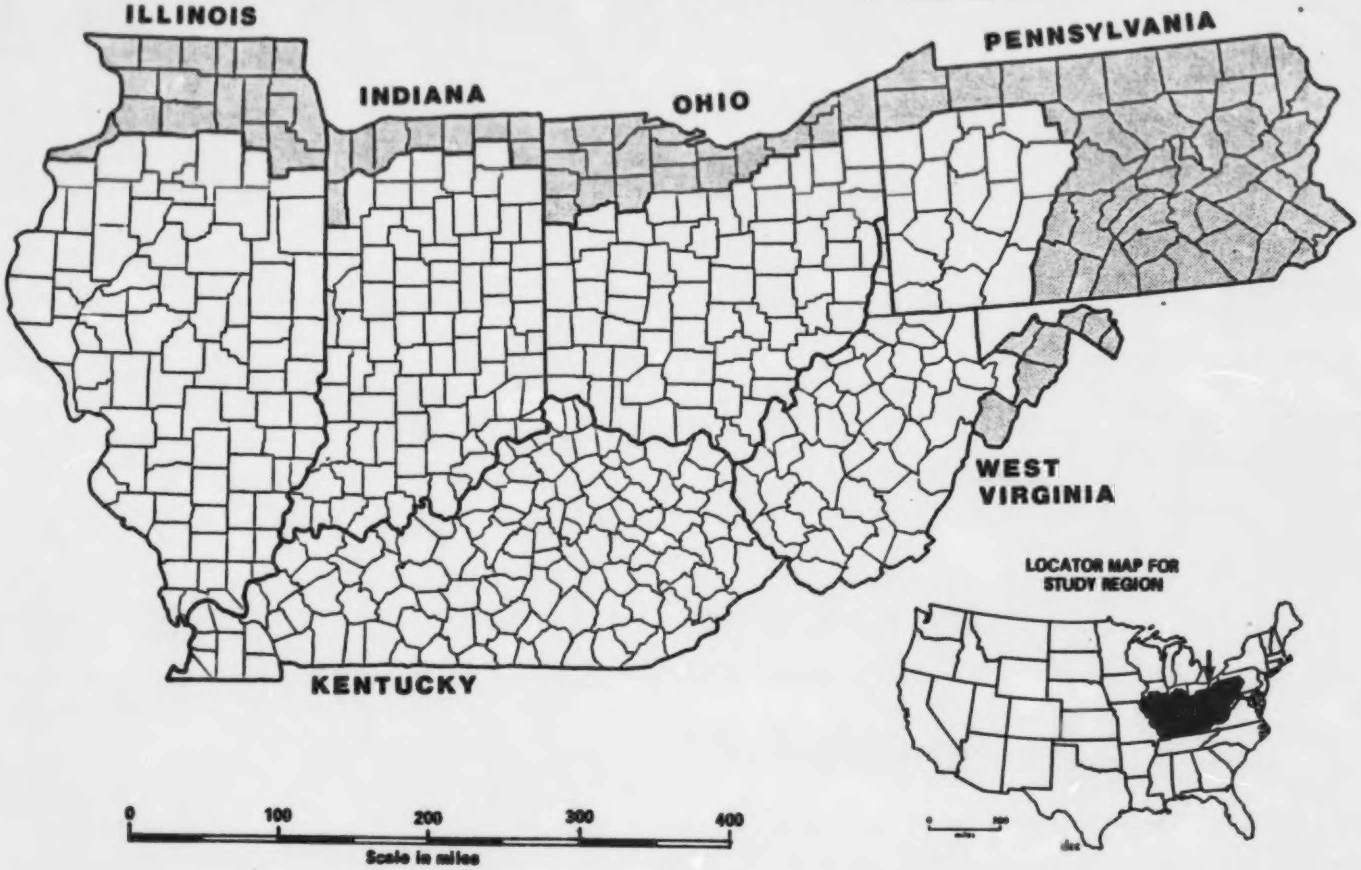
Regional technology assessments are most useful if they evaluate the impact that are associated with different scenarios and related sets of policies. Estimates of the changes in impacts that result from different policy options provide important, if not essential, information to policymakers (cf. Fowler, 1977; White and Hall, 1978). These options may include policies that affect the geographical distribution of energy facilities such as electrical generating units. Changes in policy that directly or indirectly affect the relative location of capacity additions may significantly change the nature of the resultant impacts. Whereas other regional assessments focus on a single future siting pattern, the ORBES project analyzes several.

The Ohio River Basin Energy Study (ORBES) siting model is specifically designed for regional policy analysis. The region includes 423 counties in a six-state area that focuses on the Ohio River main stem (Figure 1). Policies that indirectly affect siting generating unit additions include projections of the future production of electricity; fuel type and technologies that will meet the demand; and the resource requirements of capacity additions. Policies that directly affect siting include items such as the exclusionary requirements of technology to regulations, and preferences for one type of distribution (e.g., dispersed siting or power parks) over another. The ORBES scenarios incorporate both types of policies so that changes in impacts can be systematically evaluated. The direct effect of environmental control policies with respect to air quality, water availability, and ecological systems and land use is of particular concern.

The siting model has several important characteristics.

- Different sets of policies that directly or indirectly affect siting patterns are analyzed systematically. The pattern and type of changes in impacts that is the result of different siting patterns can be isolated and evaluated.

Figure 1. **THE OHIO RIVER BASIN ENERGY STUDY REGION**



- Announced utility plans for generating capacity additions in the near-term (i.e., 1976-1985) are combined with alternate scenarios of long-term (1986-2000) development. The base case scenario assumes that current and near-term behavior and policies will dominate the region's energy future. Other scenarios project different long-term futures which, when compared with the base case, are used to evaluate the impact of different policy options.

- Sites are defined and evaluated with respect to regional issues, resources and values. Indices of land use and ecological systems, for example, are included as siting issues. The relative importance of these other variables that affect the geographical distribution of generating unit additions, are defined by knowledgeable people.

The siting model is limited to base-loaded steam generating units that use conventional coal and nuclear fuels. Some scenarios assume alternate technologies and fuels. The alternatives affect the geographical distribution of coal-fired and nuclear-fueled generating units only to the extent that fewer conventional units need to be sited. The geographical distribution of alternate technologies is, in effect, unknown. Other models may be developed for these technologies in future assessments.

This report consists of two volumes. The methodology is presented in this volume. An analysis of siting patterns and procedures for coal-fired and nuclear-fueled generating units in the ORBES region is followed by definition of siting issues, and the methodology used in transforming the issues and related policies into future geographies of electricity supply and distribution. The siting patterns that are developed for the basic set of scenarios are compared. The second volume (Fowler et al, 1980) contains detailed lists of on-line dates and county-level sites for each scenario that was developed for the ORBES assessment.

SECTION 2

SITING ELECTRICAL GENERATING CAPACITY IN THE ORBES REGION

Siting electrical generating units is an integral part of capacity planning (Womeldorff, 1978). Given a load forecast, an array of available capacity and alternative technologies, a utility makes decisions about scheduling capacity additions at the best available sites within its service area, or adjacent service areas. Site selection takes into consideration existing environmental and regulatory constraints, as well as plant design and system economics. Planning always involves some uncertainty about the effect of changes that may occur during the 8 to 15 years before a unit is in service.

The distribution of electrical generating capacity in the ORBES region in 1975 is the baseline for the technology assessment. Announced utility plans for the next decade (1976-1985) represent a projection of near-term changes in the geography of electrical generating facilities in the region. As such, it is a guide to the near-term impacts of aggregate patterns of energy development and to policy issues. In the long-term, capacity additions are sited according to alternate development scenarios that systematically change policies that affect the distribution of electrical generating units.

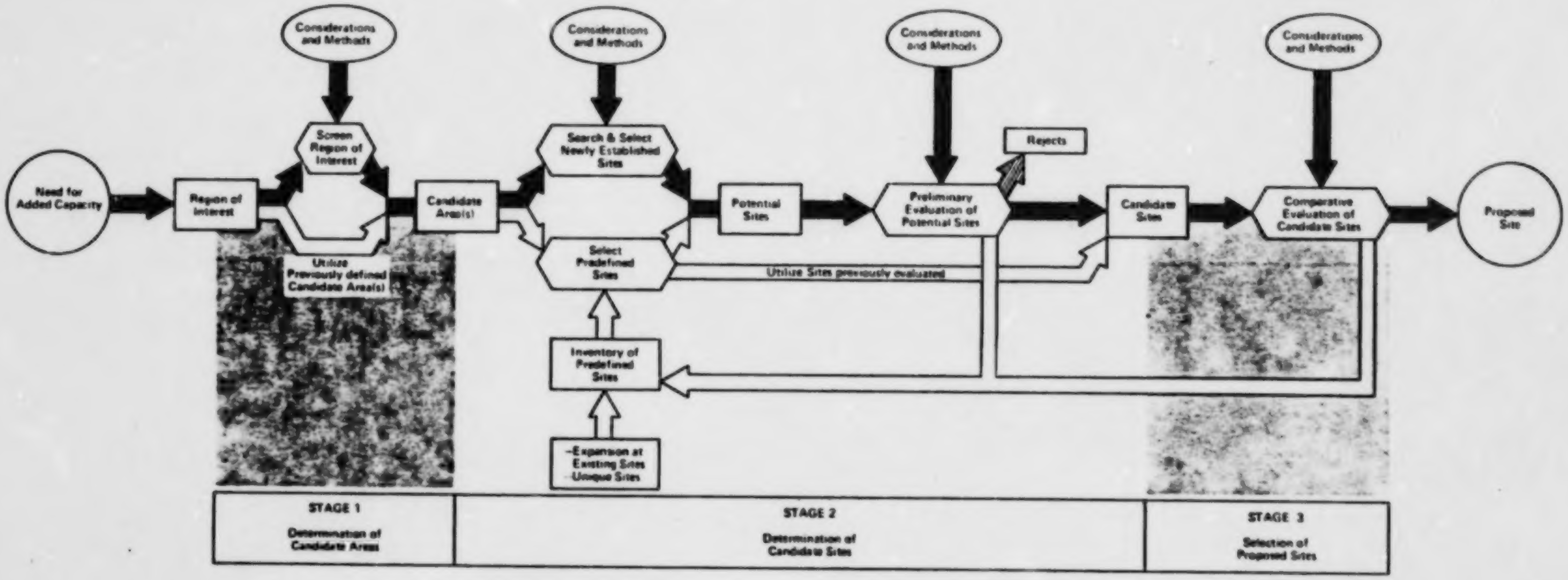
SITING PROCEDURES

General Methodology

There is no single best method or set of criteria for selecting and evaluating sites for capacity additions. Siting procedures depend upon a utility's experience and situation, including the available technological choices; the regulatory environment within which decisions are made; and the resources within the region of interest. A synthesis of the procedures that utilities use in locating nuclear-fueled units, however, suggests a generalized site selection process that incorporates, in sequential form, the basic steps involved (Figure 2).[1] The sequence leads from a systematic screening at macro-geographic, or regional, scale to an evaluation of a few proposed sites at micro-geographic scale. At each step, specific criteria are used to evaluate places as sites for capacity additions. System planning; safety concerns; engineering characteristics of the plants; environmental, institutional and regulatory constraints; and economic factors are issues in the siting process. The emphasis generally shifts from initial concerns about system planning to engineering, environmental and regulatory concerns in Stage 2, and to engineering and environmental issues only in Stage 3. Also, the degree of detail in the data required to evaluate sites increases as the number of possible sites decrease.

The determination of need for additional generating capacity, and definition of the technological alternatives available to meet that need, is the first step in the siting process. The utility's objective is then to select

Figure 2. GENERALIZED SITE SELECTION AND EVALUATION PROCESS


Need for Added Capacity
Region of Interest
Considerations and Methods
Screen Region of Interest
Utilize Previously defined Candidate Area(s)
Candidate Area(s)
Considerations and Methods
Search & Select Newly Established Sites
Select Predefined Sites
Inventory of Predefined Sites
-Expansion at Existing Sites
-Unique Sites
Potential Sites
Considerations and Methods
Preliminary Evaluation of Potential Sites
Rejects
Utilize Sites previously evaluated
Candidate Sites
Considerations and Methods
Comparative Evaluation of Candidate Sites
Proposed Site
STAGE 1
Determination of Candidate Areas
STAGE 2
Determination of Candidate Sites
STAGE 3
Selection of Proposed Sites

SOURCE: Calvert, Heilman and Smith (1974).

the best site from among those that are available to it within its region of interest. The region of interest (ROI) is the geographical area within which the utility could conceivably locate capacity additions. It may be the utility service area; the service areas of adjacent utilities; the combined service areas of pooled utility groups; or a state. The definition of the ROI is essentially a political issue (Keeney et al, 1978). The size of the regions has increased because the political problems of siting generating units have tended to favor more remote locations, and technological improvements have made long-distance transmission of power more feasible (cf. Morrill, 1977).

The objective of Stage 1 is to reduce the ROI to a relatively small group of candidate areas that are likely to have a number of suitable sites. Exclusionary screening to determine general environmental suitability is the method most commonly used.[2] Areas are excluded if they fail to meet some minimum performance standard or resource requirement. Exclusionary thresholds for selected technological and regulatory criteria can be defined in objective quantitative terms. However, not all siting issues have exclusionary characteristics.

The objective of Stage 2 is to select a relatively small number of sites within the candidate areas that can be licensed and developed. The roster of candidate sites can include the inventory of sites that have been evaluated previously, or existing sites that can accomodate additional generating capacity. The comparative evaluation of sites according to multiple criteria is the method most commonly used at this stage. This usually involves using numerical scoring procedures, and weighting each criterion according to its relative importance in siting, in order to evaluate and rank candidate sites. Whereas secondary data are generally adequate for Stage 1, more detailed data, some of which may need to be collected from primary sources, is frequently required in Stage 2 and 3.

The objective of Stage 3 is to select the proposed site from among a few high-ranking candidates. Usually, the methodologies used to evaluate the candidate sites are more complex than those used in previous stages, and more detailed site-specific data are required. The siting methodologies incorporate methods of weighing economic costs, engineering and environmental impacts, and other relevant siting criteria in order to justify the selection of one site from among a relatively few alternatives. Frequently, the selection is based upon the comparative evaluation and ranking of the candidate sites identified in Stage 2.

Siting Coal-Fired and Nuclear-Fueled Generating Units

Coal-fired generating units account for the majority of the electricity produced in the United States, as well as the ORBES region. Recent national energy policies have emphasized the increased use of coal to fuel electric plants. Coincidentally, the environmental and institutional constraints on licensing, siting and operating coal-fired units have increased. The paradox of this situation is that relatively little attention has been given to establishing standard siting and licensing procedures for coal-fired units that are comparable to those for nuclear facilities (Feldman, 1978; Williams, 1978).

Resource constraints and environmental regulations are the most important considerations in siting coal-fired capacity additions. These include ambient air quality standards; water quality standards; and ecological issues such as rare or endangered species, other unique habitats, and public or protected natural lands (Envirosphere Company, 1977). The availability of an adequate supply of cooling water, accessibility by barge or rail transport for coal, and compatible land uses are also important criteria. Coal-fired generating units must compete for scarce natural resources and, in portions of the ORBES region, with highly productive land uses such as agriculture. Siting issues also include problems from residuals such as air pollution and solid waste management (Calzonetti, 1979).

The siting procedure for nuclear-fueled units is more clearly defined because of the NRC's licensing process. According to 10 CFR 100, nuclear reactors are expected to (10 CFR, Part 100, p. 544):

> ... reflect through their design, construction and operation an extremely low probability for accidents that could result in release of significant quantities of radioactive fission products. In addition, the site location and engineered features included as safeguards against the hazardous consequences of an accident, should one occur, should ensure a low risk of public exposure.

Subsequent regulatory guidelines specify the factors to be considered and their definition for siting. These factors include reactor design; population distribution and density near the site, and distance from population centers; and physical characteristics of the site, such as seismology, meteorology, geology and hydrology.[3]

In choosing candidate sites, the availability of cooling waters, site geology, accessibility and land use are the most important criteria that utilities consider (U.S. NRC, 1976). Meteorology, population density and distribution, seismology, transmission requirements and aesthetics are less important. Whereas system planning is important in Stage 1 regional screening, emphasis shifts to a larger number of engineering, environmental and institutional criteria in determining candidate sites. A long list of engineering and environmental criteria are used in Stage 3 to evaluate and select proposed sites. Here the focus is on design and site characteristics, as most other issues have been satisfactorily resolved in earlier stages of the site selection process.

SITE SELECTION IN THE ORBES REGION

The site selection processes of utilities in the ORBES region follow general patterns. The service area is their primary region of interest. In some cases, such as Indianapolis Power and Light Company (IPALCO), the service area is small with little, if any, possibility that additional coal-fired generating units can be located in it (Saper and Hartnett, 1978, pp. 10-20). At the other extreme is American Electric Power (AEP), with member companies whose service areas are in several states and a wide range of siting opportunities. Most utilities in the ORBES region, however, have service areas that are comprised of all or portions of relative large numbers of contiguous counties within state boundaries. Their ROI's include adjacent service areas or the entire state in which they are located (cf. Elkins and DiNunno, 1975; Soyland Power Cooperative, 1980).

The siting criteria that are most important in selecting a site for a particular type of generating unit will vary according to the environment and resources that are available in the ROI. For example, Louisville Gas and Electric's (LG&E) decision to site four coal-fired units (a total of 2,304 MWe) in Trimble County, Kentucky was based upon five factors (USEPA, 1978).

1. Ample acreage for plant facilities and solid waste disposal.
2. Easy access to the Ohio River main stem for a cooling water supply and barge transport for coal.
3. Near existing transmission line tie-in.
4. Low concentrations of sulfur dioxide (SO_2) in the area.
5. Located near major population concentrations in the northern part of LGE's service area.

At larger scale, ambient air quality is the most important environmental consideration, followed by ecological criteria (primarily endangered species), water availability, geotechnical factors (mined areas and geological hazards), land use and accessibility (Elkins and DiNunno, 1975; and Soyland Power Cooperative, 1980, p. C-19). Accessibility to transmission lines is the most aspect of the latter issue because all but a few of the counties in the ORBES region have railway lines or waterways that can be used for coal barge traffic.

Nuclear reactor siting also follows general procedures (Laney and Gustafson, 1979). Although reactor safety issues dominate the initial considerations, environmental issues have exerted an increased influence on site selection and evaluation since 1970 as regulatory requirements have become more complex. In Illinois, for example, sites that are well-connected to the utility grid; are near large supplies of cooling water; and are relatively remote from densely-populated areas are preferred. Physical characteristics of the site, ecological impacts and land use compatibility are also of concern. Locating nuclear reactors in the prime agricultural lands of northern and central Illinois is definitely an issue. The utility's problem is to minimize the costs of acquiring and developing land for new sites and transmitting the electricity while maximizing safety and system reliability.

Siting in the ORBES region is primarily the responsibility of utilities operating within the framework of state policies and procedures. A majority of the states in the nation have introduced diverse legislation designed to increase the state's role in siting process (cf. Southern States Nuclear Board, 1978; Williams, 1978). In the ORBES region, Kentucky and Ohio have specific comprehensive procedures that deal with siting electrical facilities.[4] Kentucky has a system of multiple approvals for electrical power generators (except those that are municipally owned) and transmission line $\geq$ 400 kv. The Ohio Power Plant Siting Commission is the lead agency in a one-stop process that includes all electrical generating facilities (oil, coal and nuclear fuel) of $\geq$ 50 MWe, electrical transmission lines of $\geq$ 125 kv and gas transmission lines $\geq$ 125 psi. Other states do not have overall policies or procedures for siting electrical energy facilities, although task forces have studied the issue, and legislation has been introduced in Indiana and Illinois (Nelson and Mitchell, 1979). The Ohio River Valley Water Sanitary Commission (ORSANCO) has proposed a regional siting authority for all energy facilities in its member states, which includes all of those in the ORBES region (ORSANCO, 1979). This initiative, as well as others that propose state siting authorities, have yet to be adopted.

TRENDS IN SITING IN THE ORBES REGION

The six states in the ORBES region had an estimated 116,524 MWe of installed electrical generating capacity in 1975 (Table 1). Coal provided 76% of the region's total capacity with oil (11.7%) and nuclear-fueled units (7.4%) the next most important sources. Ohio, Illinois and Pennsylvania had the majority of the total 88,602 MWe installed coal-fired capacity. The seven nuclear reactors located in northern Illinois were the only such units in the ORBES region. No other state had installed nuclear capacity in 1975. The total installed capacity in a state is a function of total state population ($r^2 = 0.99$, with 1970 population data). Kentucky and West Virginia were the exceptions, as each exported almost twice the amount of electricity consumed in the state. Electricity produced in the ORBES region is also exported across the region's boundaries to the non-ORBES portion of each state subregion (Page, 1979, Appendix A).

The majority of the total 1975 generating capacity was located along the Ohio River main stem (28.7%) and its major tributaries (31.8%).[5] All of this capacity came from coal-fired units, most of which were concentrated along the Ohio upstream from Louisville, Kentucky (Figure 3). Approximately 60% of the state of Ohio's capacity, and most of that in Kentucky, Pennsylvania and West Virginia were along the Ohio and its tributaries. Other concentrations of electric generating capacity were either in or near major load centers, such as metropolitan areas, or along the Great Lakes outside of the ORBES region. Nuclear unit additions were concentrated in areas that already had nuclear capacity (Figure 4). These were relatively close to large metropolitan areas, especially Chicago.

Electrical generating capacity in the six-state region is expected to nearly double from 1976 to 1985. Fifty-three percent of the net 56,361 MWe projected increase is from coal-fired generating units, with nuclear-fueled units accounting for 44% of the total (Figures 5 and 6). Nearly one-half of the scheduled additions are expected to be in Illinois and Pennsylvania, primarily because of the large increases in nuclear-fueled capacity in these states. Coal-fired units account for all of the scheduled additions in Kentucky and West Virginia, and three-quarters of those in Indiana. The majority (58%) of the total coal-fired capacity additions, as well as the additions in Kentucky, Ohio and West Virginia, are sited along the Ohio River main stem. Another 30% of the total will be located on tributaries of the Ohio; nearly

Table 1. SUMMARY OF ELECTRICITY GENERATING CAPACITY, 1975, AND CHANGES, 1976-1985
SIX-STATE REGION

State	Fuel Type, MWe						MWe	
	Coal	Nuclear	Petroleum	Natural Gas	Hydro[a]	Other[b]	Total	% Total
Illinois	15,801	5,717	4,058	204	34	197	26,011	22.3
Indiana	13,104	-	1,166	110	114	324	14,818	12.7
Kentucky	10,948	-	121	128	679	-	11,876	10.2
Ohio	21,266	-	2,700	71	1	626	24,664	21.1
Pennsylvania	15,517	2,904	5,818	19	1,717	815	26,790	22.9
West Virginia	11,966	-	12	-	205	387	12,570	10.8
TOTAL	88,602	8,621	13,875	532	2,750	2,349	116,729	100.0
% Total	75.9	7.4	11.9	0.4	2.4	2.0	100	
1985 Capacity MWe	118,572	33,240	14,087	456	3,037	3,493	172,885	
1975-1985 MWe Change, Net	29,970	24,619	212	76	387	1,144	56,156	
1975-1985, % Change	+ 33.8	+ 285.6	+ 1.5	- 14.3	+ 10.4	+ 32.8	+ 48.1	

SOURCE: S. D. Jansen (1978).

[a] Includes hydro and pumped storage.

[b] Includes refuse, waste heat, multi-fueled and unknown fuel types.

Figure 3. TOTAL INSTALLED COAL-FIRED ELECTRICAL GENERATING CAPACITY, 1975
SIX-STATE REGION

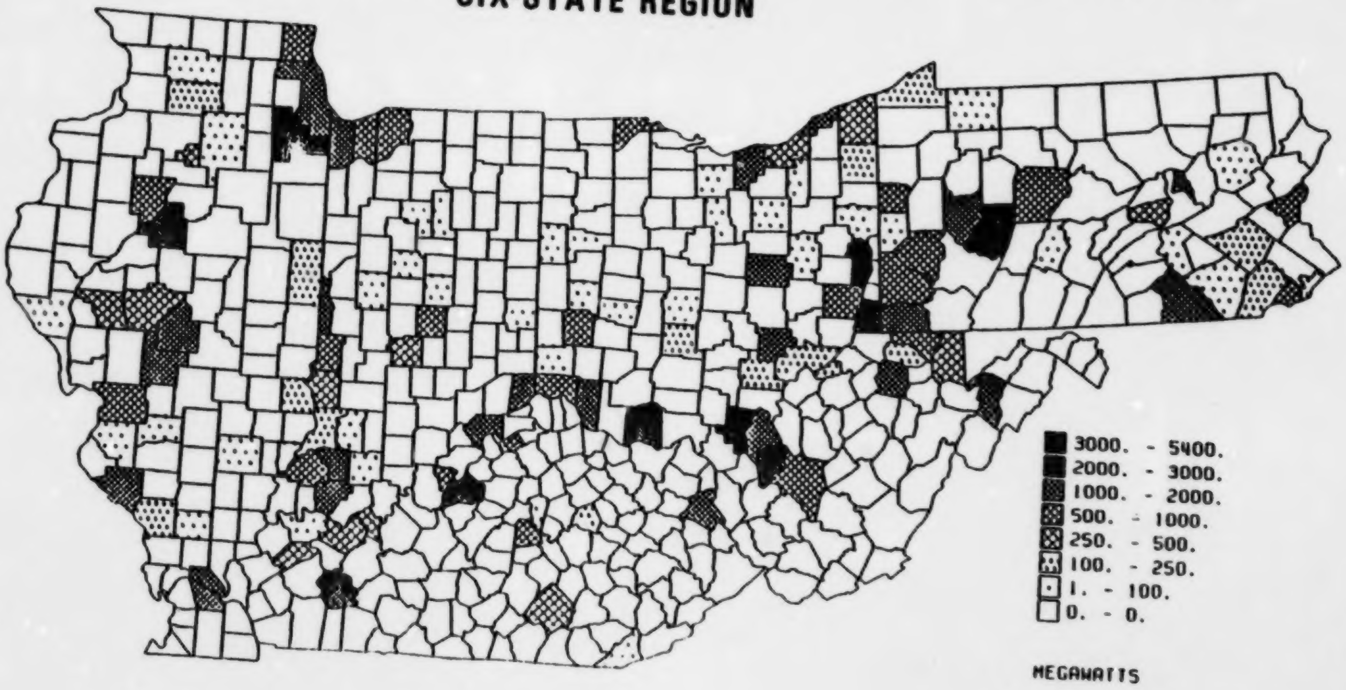


Figure 4. TOTAL INSTALLED NUCLEAR-FUELED ELECTRICAL GENERATING CAPACITY, 1975
SIX-STATE REGION

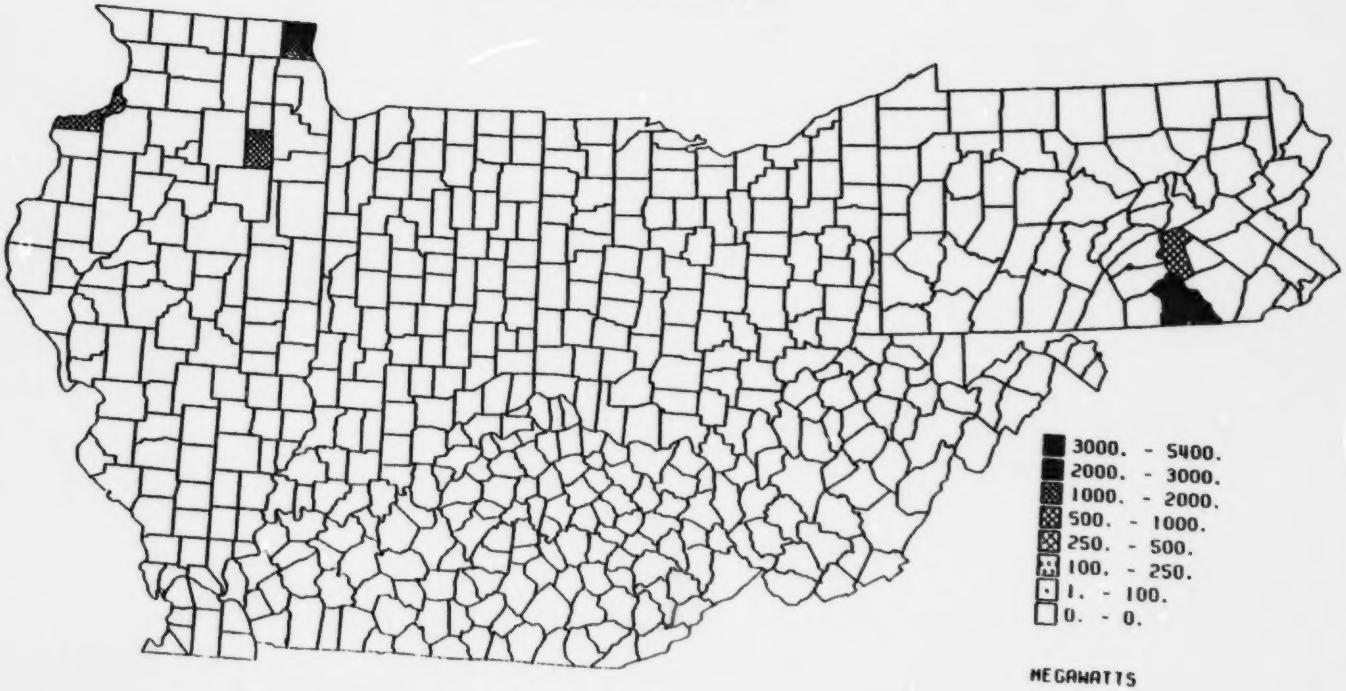


Figure 5. TOTAL PROPOSED COAL-FIRED ELECTRICAL GENERATING CAPACITY ADDITIONS, 1976 1985 SIX-STATE REGION

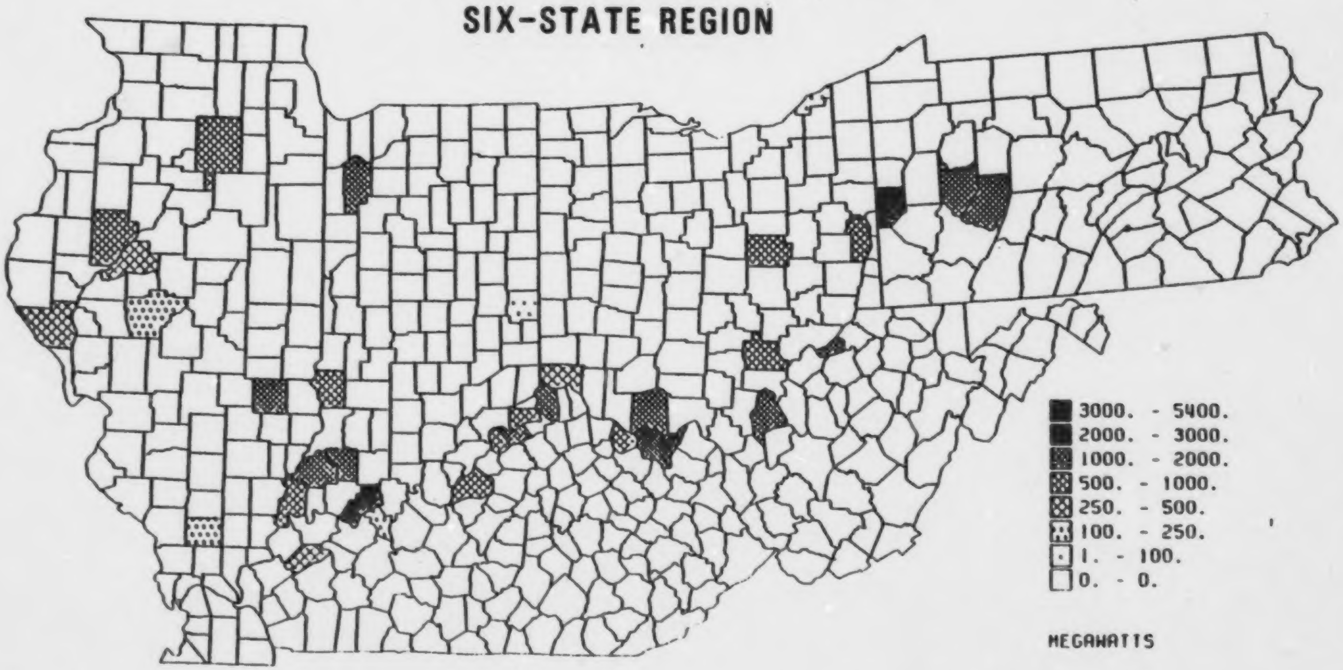
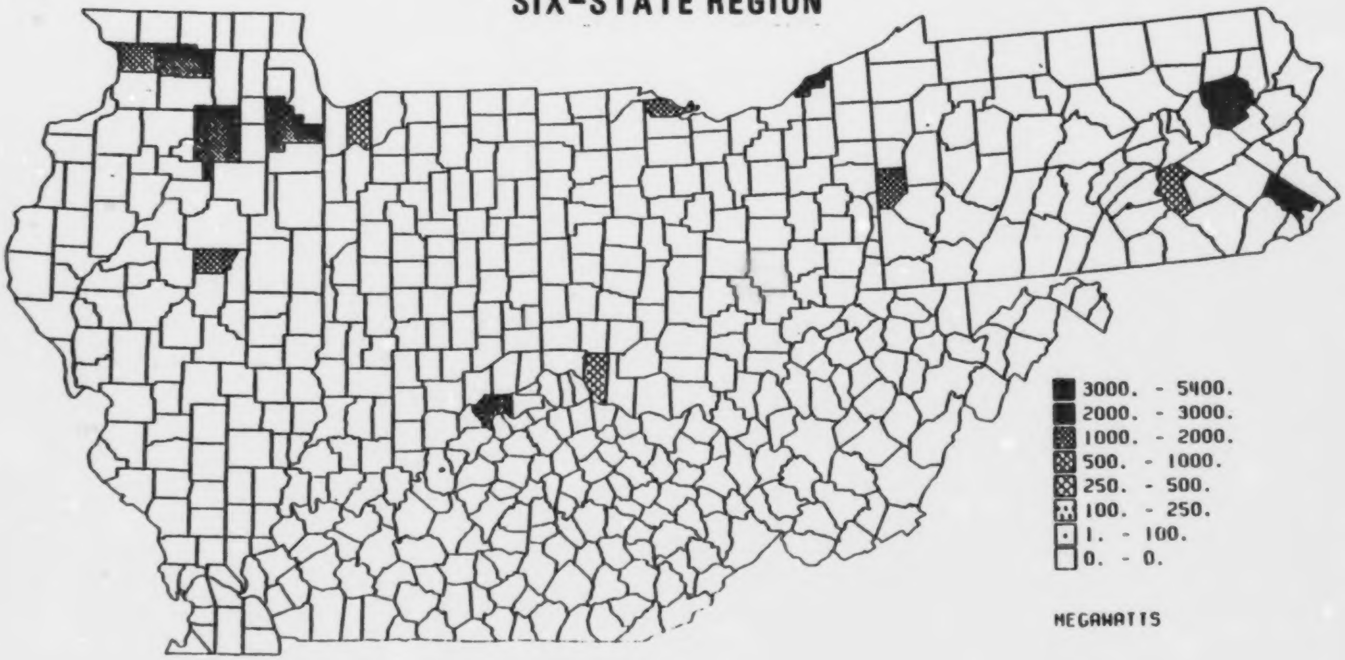


Figure 6. TOTAL PROPOSED NUCLEAR -FUELED GENERATING CAPACITY ADDITIONS, 1976 1985 SIX-STATE REGION



one-half of Indiana's scheduled capacity additions will be at sites along the Wabash and White Rivers.

Nuclear-fueled units comprise a large portion of the total scheduled capacity additions in Illinois, Ohio and Pennsylvania. Eighty percent of the total 24,619 MWe of new nuclear capacity are for sites located outside of the ORBES region. Although Indiana and Ohio have scheduled nuclear capacity additions for the first time, the majority of the nuclear expansion continues to be in parts of the region that had nuclear capacity in 1975. Nuclear plants are located outside the major coal-producing areas, many of which have seismic risks. Neither Kentucky nor West Virginia scheduled nuclear-fueled units through 1985, thus continuing their preference for coal-fired electric generating capacity.

Several trends in siting coal-fired and nuclear-fueled generating capacity additions through 1985 in the ORBES region are apparent.

1. The size of electric generating units and plant sites is expected to increase (Table 2).

   This trend has accelerated rapidly since about 1960, both in the ORBES region (Saper and Hartnett, 1979, pp. 10-21) and in the United States (Cirillo et al., 1977). The generating unit additions and plant sites in the ORBES region, however, are more than twice as large as the national average (in 1974). As a consequence of these trends, fewer sites are required for capacity additions.

2. The majority of the coal-fired capacity additions are scheduled for new and larger sites. Nuclear-fueled units are also on new sites, although they are not significantly larger than in 1975.

   Sixty percent of the coal-fired units in the region and 96% of the nuclear-fueled units are scheduled for new sites. By comparison, 75% of the coal-fired units in the nation are scheduled for new sites (Cirillo et al, 1977). The East Central Area Reliability (ECAR) Council has identified 12 of the 36 current sites in its area as "expandable," i.e. they can physically accomodate some generating capacity additions.[6] According to Burwell, Ohanian and Weinberg (1979), three of the four nuclear reactor sites in ORBES states can also accomodate additional capacity.[7]

   Many of the coal-fired sites cannot easily accomodate additional capacity because of air quality constraints in heavily industrialized urban areas. Many of these are relatively old, smaller units that can burn oil or other fuels. In other cases, especially in the ORBES region, large units can be added to existing sites if they burn low-sulfur western coal, or if they add pollution control technologies. Few sites are actually closed when existing units are retired, as utilities retain them for use by types of capacity that use other fuels.

Table 2. SIZE, IN MWe, OF COAL-FIRED AND NUCLEAR-FUELED ELECTRICAL GENERATING UNITS AND SITES, SIX-STATE REGION
(Steam Units Only)

		Fuel		Size, in MWe		
		Coal	Nuclear	Mean	Maximum	Minimum
1975						
Operating	Units	●		190	1,300	1
	Sites	●		546	2,932	2
	Units		●	862	1,098	209
	Sites		●	1,724	2,196	818
1976-1985						
Planned	Units	●		549	1,300	20
	Sites	●		1,349	2,751	480
	Units		●	1,023[a]	1,205	60[b]
	Sites		●	1,688[a]	2,410	810

SOURCE: Jansen (1978).

[a] Mean site calculated excluding 60 MWe Shippingport experimental Light Water Breeder Reactor.

[b] Shippingport experimental Light Water Breeder Reactor.

3. Capacity additions, especially coal-fired units, are sited away from metropolitan areas and other concentrations of population.

The majority of the coal-fired capacity additions in the ORBES region are scheduled for areas with relatively low population density along the Ohio River main stem and its major tributaries, as well as near the region's coal resources. At national scale, the trend is toward mine-mouth siting with most additions located at sites within 50 miles of adequate coal supplies (Cirillo et al, 1977). Mine-mouth siting in the ORBES region is an attractive option in the region provided that other resources are available.

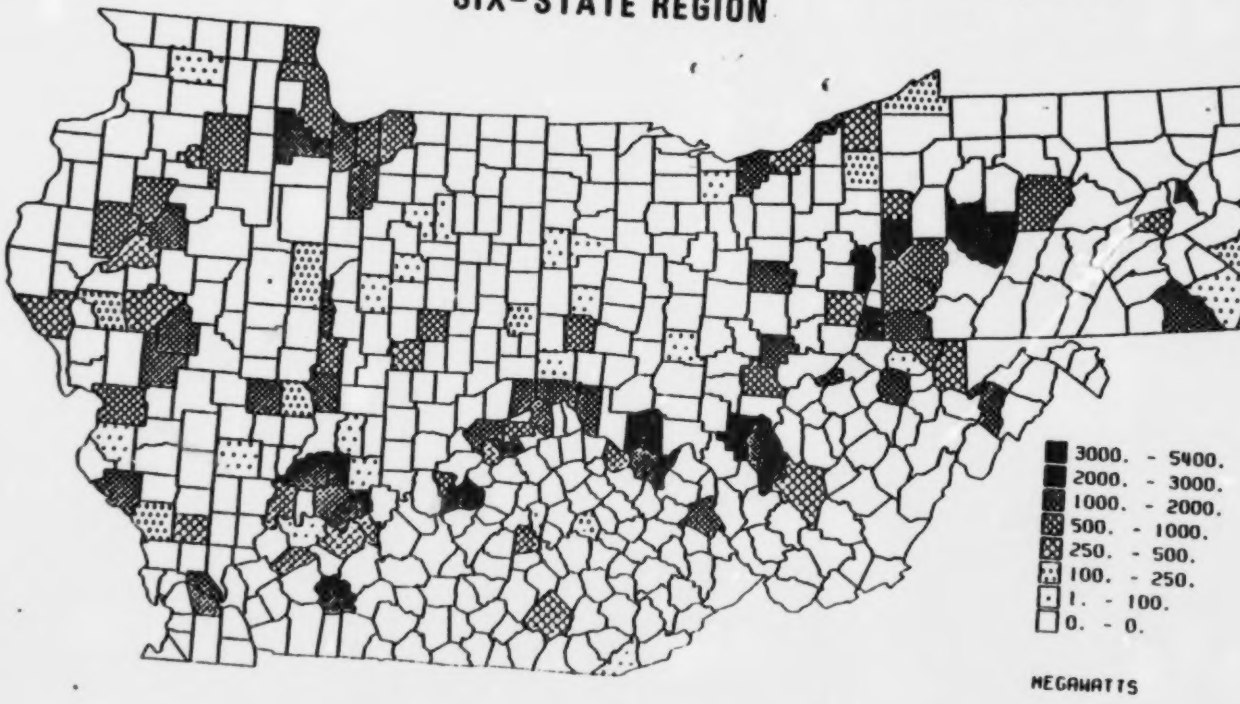
Most nuclear-fueled capacity additions are located in parts of the region that already have nuclear capacity. Others are along the Ohio River main stem. As in the nation, nuclear reactors in the ORBES region are actually sited closer to population concentrations than are coal-fired units. In this sense, issues of environmental constraints, especially with regard to air quality, and public health and safety are relative.

4. Joint ownership of generating unit capacity additions is expected to increase.

Three companies, plus Ohio Valley Electric Corporation, in the ECAR region have generation that is located outside of their service area. This represents approximately six percent of the total generation. Elsewhere, capacity additions are scheduled for sites within the service area of the utility that owns them, or that has majority control. However, joint ownership is common in the ORBES region. Approximately 38% of the scheduled capacity additions from 1976 to 1985 will be in joint ownership, which will result in an increase from 23.4% of the total MWe in 1975 to 30.5% of the total in 1985. Although jointly-owned units are concentrated in the eastern part of the region, the practice is expected to spread to each of the ORBES states. Except for Pennsylvania, all jointly-owned units in the region have at least one out-of-state partner.

By 1985, 61% of the total coal-fired and nuclear-fueled generating capacity is expected to be located in Illinois, Pennsylvania and Ohio. The most significant growth is projected to be along the Ohio River main stem, where the concentration of generating capacity would increase to 34.5% of the six state total; and along the Ohio's tributaries, where the capacity would increase to 26.5% of the total. This is primarily because of the location of new coal-fired capacity adidtions in Ohio, Indiana and Pennsylvania. These states are expected to contain 54% of the total 11,572 MWe of coal-fired generating capacity in 1985 (Figure 7). Almost three-quarters will be in the Ohio River basin, with 40% located on the main stem, (as compared to 32%

Figure 7. **TOTAL COAL-FIRED ELECTRICAL GENERATING CAPACITY, 1985**
SIX-STATE REGION



located there in 1975) and 34% on the tributaries. This projected growth would significantly increase the concentration of electric generating capacity along the main stem of the Ohio River between Portsmouth, Ohio and Louisville, Kentucky.

Most of the nuclear electric generating capacity projected for 1985 will be located in Illinois and Pennsylvania (Figure 8). These two states are expected to have 76% of the total 33,240 MWe nuclear capacity in 1985. Only three sites (Zimmer in Ohio; Marble Hill in Indiana; and Beaver Valley in Pennsylvania) will be along the Ohio River main stem. These three sites would constitute 15% of the total nuclear capacity. The remainder is expected to be located outside of the Ohio River drainage basin in northern Illinois and eastern Pennsylvania.

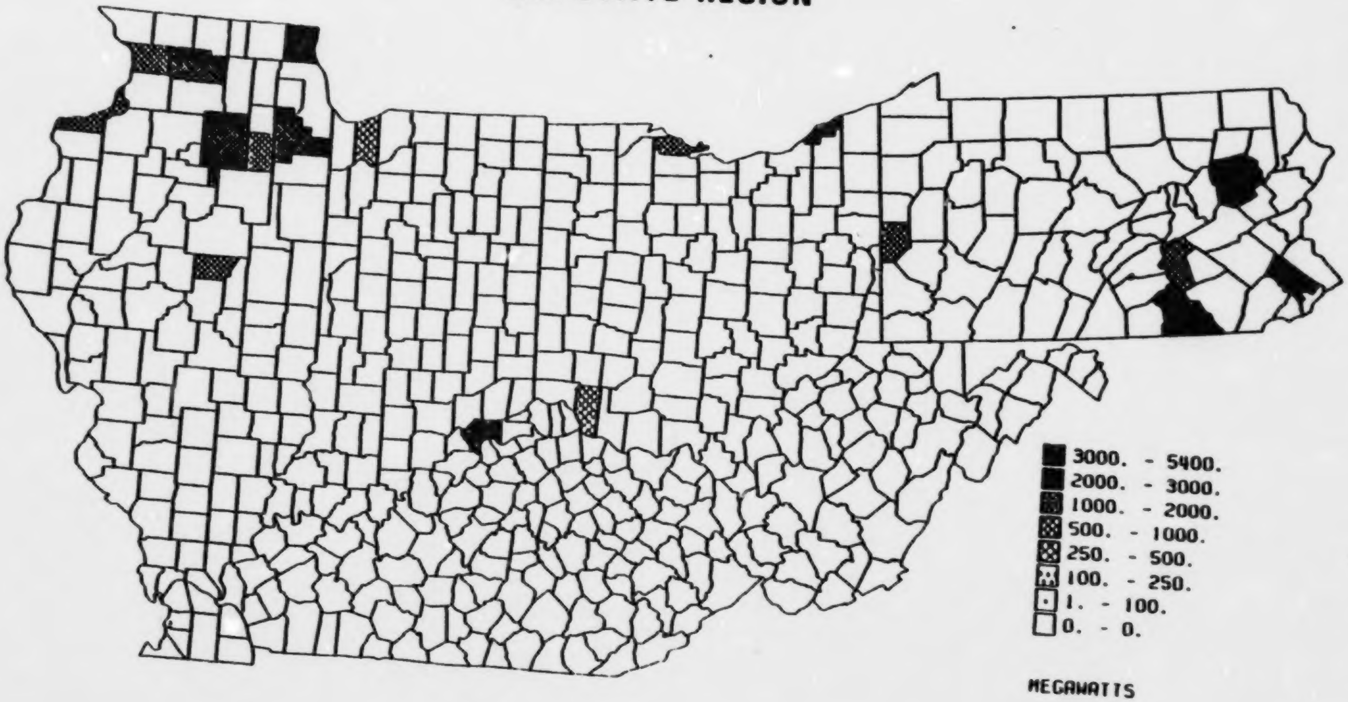
CHANGES IN THE SCHEDULE OF PLANNED ADDITIONS

The utilities constantly revise their announced plans for capacity additions. Deferrals and reduced commitments for new electrical generating capacity already had begun to result in delaying construction schedules and on-line dates in 1975 (Old, 1976; Rittenhouse, 1976). The net effect of these changes over a one year period was to reduce the expected 1985 installed capacity by 1,926 MWe. While the MWe of postponed coal units was approximately equal to the megawattage of newly announced plants, the expected nuclear capacity had a net reduction of 2,158 MWe because postponements were not compensated for by newly announced units (Saper and Hartnett, 1979). Subsequently, the extent of slippage increased, especially for nuclear-fueled units. The National Coal Association has reported that in 1979, 57% of new coal-fired capacity, and 71% of new nuclear-fueled capacity, experienced delays. The most common reasons for the delays are:[8]

> ... revisions in forecast demand for electricity, delays in siting or licensing, problems with preparation of environmental data or financial uncertainties.

The changes in scheduled capacity additions in the six-state ORBES region, especially in Illinois, Indiana, eastern Ohio and Pennsylvania, have followed the general national slowdown in new power plant construction.

Figure 8. **TOTAL NUCLEAR-FUELED ELECTRICAL GENERATING CAPACITY, 1985**
SIX-STATE REGION



FOOTNOTES

[1] The generalized siting process represents a synthesis of the procedures used by 26 electric utilities for siting nuclear reactors in 1973-1974. The NRC stated that there was no reason to assume that the basic procedures had changed substantially since then (U.S. NRC, 1976).

[2] Detailed evaluations of siting methodologies are in: Keeney et al (1978); and Hobbs and Voelker (1978).

[3] The NRC currently is considering adopting new rules that will affect siting. These rules are intended to reflect the experience gained since the original siting regulations were published in 1962. They are meant to apply to facilities for which an application for construction permit is filed after October 1, 1979 (Energy Users Report, August 7, 1980, p. 10).

[4] These are reviewed in detail by McLaughlin (1980).

[5] Seventy-two of the 524 counties in the six-state region border the main stem of the Ohio River, and 276 are along major tributaries (i.e., the Wabash, Great Miami, Scioto, Muskingum, Allegheny, Monongahela and Kanawha). The remainder of the counties in the six states are in basins that drain to the Mississippi River (Illinois River), the Great Lakes and the Atlantic Ocean (Susquehanna and Delaware Rivers).

[6] See Appendix G.

[7] According to Burwell, Ohanian and Weigberg (1979), the Clinton site in Illinois cannot be expanded beyond current utility plans. Other nuclear sites in the ORBES region can accomodate additional capacity.

[8] Energy Users Report, December 20, 1979, p. 12. According to a recent DOE analysis of construction delays of coal-fired generating units in the first nine months of 1979, utilities in the ORBES region had a net loss of 26,245 MW-M, all of which was accounted for by delays in Pennsylvania and Ohio. On-line dates were advanced for units in Kentucky and Indiana (U.S. Department of Energy, Economic Regulatory Administration, 1980).

SECTION 3

THE OHIO RIVER BASIN ENERGY FACILITY SITING MODEL

Forecasting the future geographical arrangement of energy facilities is an essential step in converting energy supply scenarios into a geographical pattern of impacts that can be assessed. Economic and technological factors dominate decisions about the location of large facilities at national scale (Willbanks and Calzonetti, 1977). At regional scale, the consideration of environmental impacts and resource use are important influences in the future geography of electrical generating units and similar energy facilities.

The ORBES siting model is designed for use in regional technology assessments of energy development scenarios that emphasize electrical generation. It incorportates selected features of other regional siting models into a process that simulates current and projected siting practices of utilities in the region, and that is sensitive to regional resources and values. Scenario policies that change these conditions may also result in significantly different siting patterns. The assessment of changes in impacts will help to anticipate the political geography of future energy supply policy.

REGIONAL-SCALE ENERGY FACILITY SITING MODELS

The role of energy facility siting models in regional technology assessments is to translate energy supply scenarios into a geographical pattern of impacts. These scenarios, and their associated policies, generally specify levels of energy production for some future date, or dates, as well as the distribution of that production among several sources and technologies. The scenarios generally describe conditions at national, and sometimes regional, scale. Environmental assessment models, however, generally require more precise geographical locations of projected facilities in order to provide useful information about their cumulative impact under different policies. The critical issue is geographical scale (Meir, 1977c; Palmadeo, 1976).

Within a region, the problem is how to distribute relatively large numbers of hypothetical energy facilities in a manner that is consistent with scenario policies, energy technology mix, and the available resources and regional values. Several comprehensive models have been developed to solve this problem. One group, which Church and Hillsman (1979) refer to as "regional siting policy models," define optimal siting patterns to meet the constraints imposed by public policy and regulations (Eagles, Cohen and ReVelle, 1980; Meir, 1977a and 1977b; and Provenzano, 1978). Baseline siting simulation models constitute a second group (Davis et al, 1978; Dobson, 1979; and Van Horn, Liroff and Hirata).[1] These models project plausible, rather than optimal, facility locations in consideration of public policy and regulatory constraints. Although neither approach will predict actual sites for individual facilities, they will provide the basis for assessments of the trade-offs that may be involved under different policy options. This type of information is necessary for informed decision-making about the political geography of energy supply policy.

Each model has certain parameters that are specified by the user. These parameters, and their definition in the models reviewed here, are

1. The regions-of-interest (ROI) are generally composed of contiguous states located in the eastern part of the United States.

   The multi-state regions also coincide with the extent of power pools or other energy planning regions. Individual states and subregions of a state may also be significant for energy planning.

2. Most scenarios project current (i.e., mid-1970s) conditions to the year 2000 or 2020.

   The "future" is divided into two periods. In the near-term--for example, 1975 to 1985--the geographical distribution of electrical generating facilities depends upon existing and announced utility plans. Beyond the mid-point, the siting model is responsible for locating capacity additions that are required to meet final year production.

   Most of the models are static. That is, they describe siting patterns for particular years--1975, 1985 and 2000 or 2020. Consequently, impact assessment depends upon the definition of incremental change, for each scenario, from one end year to another. The Utility Simulation Model (Van Horn, Liroff and Hirata) is the only siting model to schedule electrical generating capacity additions on a continuous, year-by-year basis.

3. The energy supply technologies are large, central station base-load steam electrical generating units that are fueled by either coal or uranium.

   The units range in size from 850 MWe to 1100 MWe, and may vary in terms of cooling options. Otherwise, they are conventional technologies. The type and mix of technologies that a scenario projects are important because they affect the policy issues and options, as well as the evaluation of resource requirements and the range of expected environmental impacts. Alternate technologies are usually considered to the extent that they may reduce the amount of energy that conventional facilities must supply.[2]

4. "Sites" are either counties, minor civil division, or small rectangular cells based upon conventional map grid coordinates.

The "site" is the smallest common geographical area in the model. It is the unit for which data on siting variables are gathered, and in which facilities are located. Compared with the counties, the cells in rectangular grids are smaller and uniform in size and shape. They provide a consistent base for collecting and analyzing environmental information. However, a wider range of socioeconomic data are available for counties.

5. The suitability of sites for new energy facilities are evaluated according to issues related to the technological characteristics of a facility, its resource requirements, and regulatory constraints that affect its location and operation.

Air quality, water availability, land use and ecological impacts and fuel resources are common issues in siting coal-fired generating units. Public health and safety is important also for nuclear-fueled units. These are general concerns throughout each region and can be defined for large areas. Whereas socioeconomic issues are represented to some degree, public acceptability is not considered in the siting models.[3]

Regional Energy Supply

Energy scenarios specify total regional energy supply, or production, for some future time and the mix of technologies that will provide it. In order to be useful for siting models, this information must be disaggregated within a framework of smaller geographical areas in the region. States, economic regions (e.g., Bureau of Economic Analysis regions) and utility service areas have been used, with the total population in each subregion as the most common denominator for disaggregating regional energy supply projections. Within each subregion, supply may be assigned to one or several "load centers" (usually cities and metropolitan areas), also on the basis of population. The exchange of energy across subregional boundaries is not considered.

Existing generating capacity and planned additions represent a portion of the future geographies of energy supply facilities. In most cases, these are considered to be sufficient to meet supply in the near-term, e.g. from 1975 to 1985. In the long-term, most if not all of the supply presumably will be provided according to scenarios that specify the mix and characteristics of technologies, as well as policies that may significantly alter siting patterns. The ANL (1978) model assumes that the sites of current (1975) and planned (1985) capacity will have the same size and type of plants in 2000 and 2020. They argue that utilities will add new units of the same or larger size if older plants are retired from existing sites rather than compete for scarce new locations. The schedule of unit retirements can be a significant factor in the long-term, especially if "new" units are assigned a different fuel. This is the case in the Northeast region, where a large portion of the existing facilities use oil and may be replaced by coal-fired units (Meier, 1977a).

Definition of Site Suitability

Definition of the suitability of sites as locations for generating unit additions usually involves three steps:

1. Specific criteria are selected that can be used to define the compatability of site characteristics with technological and regulatory siting issues.
2. The region is screened to exclude those sites that are not likely to have a suitable location for a given facility.
3. The remaining candidate sites are compared with one another in order to define their relative suitability as locations for future facilities.

The usual procedure is to project current conditions into the future, and then change the definition of suitability to accomodate different technologies; regulatory policies, especially with respect to environmental controls; or even resource availability, expecially coal production. This is accomplished by the selection of exclusionary criteria and the relative importance that is given to each factor in defining the suitability of candidate sites.[4]

The definition of site suitability is sensitive to the choice of criteria that represent the siting issues, and their translation into measures of compatability with a particular technology or policy. Most models depend upon a small a priori list of criteria that are closely related to the technological characterisitcs of the facility and regulatory issues, and that can be measured with readily-available data. The issue of water availability, for example, is measured by the consumptive use or withdrawal requirements of a particular cooling system relative to the low flow stream volume under drought conditions, In turn, the value of a criteria at each site is assessed on a common scale in terms of its "compatability" with the technology and regulatory environment. If safety is an issue for nuclear-fueled units, densely-populated areas are less-desireable (i.e., less 'compatible') as sites than are sparsely-populated areas. The expected relationship is inverse. In the case of water availability, however, locations that are close to streams that have large consistent flows are highly valued (i.e., more 'compatible') as sites for all types of technologies. The choice of campatability scales can vary considerably unless technological constraints of the facility or regulatory rule-making sets some standard of performance, or resource requirement that define threshold values for siting criteria.

Exclusionary screening uses threshold values to filter out those sites that are not likely to contain suitable facility locations.[5] The translation of these values into siting constraints may vary widely, especially where proximity to an area that is unlikely to contain a suitable site is involved. The issue of separation distances and buffer zones in relationship to air quality issues is a case in point. The definition of exclusionary criteria and thresholds may change to reflect different policies and regulations. Consequently, they may significantly affect the geographical distribution and characteristics of candidate regions, as well as the nature and concentration of the resultant impacts.

Finally, the candidate sites are compared with one another according to the selected criteria in order to determine their suitability as locations for new facilities. Weights assigned to each criteria reflect their relative importance in the siting decision. Models that concentrate on the influence of a single criteria, such as water availability, usually assign weights on an a priori basis. Models that are concerned with decisions that involve numerous factors are more likely to rely on the consensus of expert panels to define the relative importance of each.[6] Optimization models, on the other hand, define suitability in terms of objective functions such as minimizing costs of transportation (of electricity or coal), augmenting water supplies, or environmental impacts. Because of importance weights, definition of site suitability can incorporate the effects of specific technological and regulatory changes that affect new facilities, as well as general shifts in the policy environment.

The way in which the models define site suitability is subject to three criticisms. First, the procedure is basically judgemental. Technical justifications are necessary to support each decision, although some models are ambiguous. The importance weights are supposed to reflect group values, although siting "experts" dominate the panels. Second, none of the models actually determine whether or not different sets of policies and regulatory decisions create significantly different suitability patterns. Keeney et al (1979) report that whereas lists of the most suitable, and the least suitable sites are not likely to change, the rankings of sites in the medium suitability range can shift significantly. This is important in the long-term, as new facilities are more likely to be located in such places as the few best sites are developed. Third, the siting criteria generally do not change through time. Except for population projections, current conditions are assumed for all future time periods. They do not change, even to reflect the synergestic affects of incremental siting decisions.

Allocation of Additional Facilities

In the third phase of the siting models, the number and type of new facilities that are necessary to satisfy total supply are allocated to locations within each subregion, or siting region. For each technology, the facilities are allocated according to:

1. Site suitability scores[7]

2. Proximity of a site to a load center or fuel resource (e.g., mine-mouth siting for coal-fired units), constrained by one siting criteria (usually water availability) or site suitability scores.

3. Objective functions, such as minimization of transmission or transportation costs or environmental impacts.

Each model also sets a maximum total capacity that can be located at a single site. The result is to project a type of "dispersed" siting policy into the future.[8] The maximum can be increased to simulate the concentration of facilities in energy parks (Argonne National Laboratory, 1977a). Because all new facilities must be located in the region to which they are assigned, none of the models account for practices of joint ownership of facilities in other states.

The result is a geographical pattern of energy supply facilities in the region that includes two sets of facilities. One is sited according to existing or near-term conditions as evaluated by utility planners. The other is developed by the siting model according to technologies and policies that are integral parts of long-term energy supply scenarios. Teknekron's Utility Simulation Model provides a year-by-year schedule of on-line dates for new facilities in addition to the announced utility schedules for planned units. All other models provide only aggregate patterns for a particular year.

THE ORBES REGIONAL SITING MODEL

The ORBES regional energy facility siting model is a hierarchical, linear-weighted model that allocates, at county level and according to scenario policies, base-loaded coal-fired and nuclear-fueled electrical generating units in addition to those that are already in service or are planned in order to reach some future total regional energy supply (Figure 9). The ORBES model incorporates selected features of other regional assessment siting models within a framework that is designed to facilitate policy analysis. The model has three interrelated modules:

1. Disaggregation of total regional energy supply, by fuel type and technology mix, to siting regions.

2. Definition of candidate site suitability, by fuel type and scenario energy policies.

3. Allocation of generating unit capacity additions, by fuel type, to county-level sites according to scenario siting policies.

Policy changes can be simulated provided that they are functionally related by policy issues to some aspect of the model. Because the process is deterministic, the incremental changes in impacts that result from policy changes that affect siting can be estimated.

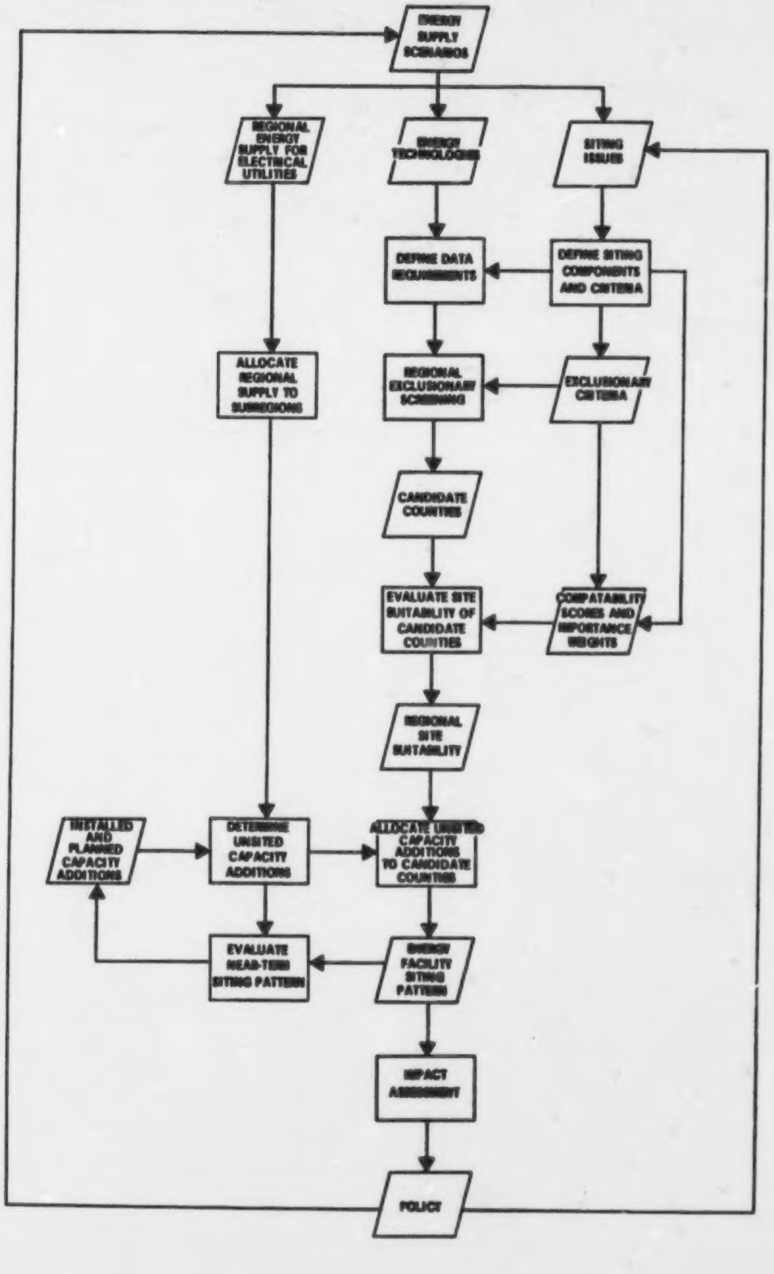
The siting model depends upon regional energy supply scenarios for three pieces of information. They are:

1. Total regional energy supply, by fuel type and technology, for some future year(s).

2. Technological characteristics of the generating units that are to be sited in the long-term (i.e., beyond utility plans).

3. Policies that may affect site suitability or siting procedures.

Figure 9. **OHIO RIVER BASIN ENERGY STUDY ENERGY FACILITY SITING MODEL**


ENERGY SUPPLY SCENARIOS
REGIONAL ENERGY SUPPLY FOR ELECTRICAL UTILITIES
ENERGY TECHNOLOGIES
SITING ISSUES
DEFINE DATA REQUIREMENTS
DEFINE SITING COMPONENTS AND CRITERIA
ALLOCATE REGIONAL SUPPLY TO SUBREGIONS
REGIONAL EXCLUSIONARY SCREENING
EXCLUSIONARY CRITERIA
CANDIDATE COUNTIES
EVALUATE SITE SUITABILITY OF CANDIDATE COUNTIES
COMPATABILITY SCORES AND IMPORTANCE WEIGHTS
REGIONAL SITE SUITABILITY
INSTALLED AND PLANNED CAPACITY ADDITIONS
DETERMINE UNSITED CAPACITY ADDITIONS
ALLOCATE UNSITED CAPACITY ADDITIONS TO CANDIDATE COUNTIES
EVALUATE NEAR-TERM SITING PATTERN
ENERGY FACILITY SITING PATTERN
IMPACT ASSESSMENT
POLICY

The total regional energy supply data, along with existing and planned capacity additions, provides the basis for calculating the amount, type and subregional distribution of projected, unmet demand within the region of interest. The technological characteristics of the scenario unit additions are used to calculate the number that are to be sited, as well as to help define the siting issues and data requirements. Siting issues include those considerations that are relevant to the location of scenario unit additions of concern to the assessment and the policies it addresses.

The final production of energy from electrical utilities in the ORBES region in the year 2000 is allocated to state subregions on the basis of the distribution of projected supply, by fuel type, in 1985. The existing generating capacity in 1975, and scheduled capacity additions from 1976 to 1985 for which county-level sites have been announced, is then subtracted from the total required capacity in the year 2000 to determine the total unsited capacity additions. Announced and expected retirements add to the total. The total unsited capacity addition for each state subregion is translated into the number of standard base-loaded coal-fired and nuclear-fueled scenario units, as specified by the scenarios, that is to be located according to the site suitability of ORBES counties and the allocation procedures for each scenario. Electricity generation with alternative fuels and technologies, and the impact conservation measures, are considered to the extent that they reduce the capacity additions in conventional technologies.

Siting issues represent scenario policies and technologies that affect the resource requirements of the electrical generating units or the regulatory environment within which they operate. The primary issues are: air quality; water availability; land use and ecological systems; seismic suitability; and public health and safety. Each of these components is represented by one or more specific criteria for which quantitative data are collected at county scale. Threshold values that define some minimum expected resource requirement or performance level for a given criterion are used to exclude from consideration those counties in which the likelihood of finding a suitable site is low. The remaining candidate counties are evaluated according to their relative suitability as sites for either coal-fired or nuclear-fueled scenario unit additions. Site suitability is determined by a two-step, hierarchical linearly weighted model. Each site is given a standardized score for each criterion, and weights derived from an expert panel are used to indicate the relative importance of each major component in siting decisions in the region. The result is a set of descriptions of site suitability for candidate counties across the region that varies by fuel type and environmental policies.

The unsited generating unit additions are then allocated on a state-by-state basis to candidate counties according to their suitability indices subject to locational constraints and scheduling patterns. In most scenarios, existing and announced utility plans provide sufficient capacity additions to meet supply projections in the near-term, i.e. from 1975 to 1985. Scenario unit additions provide most of the additional supply required from 1986 to 2000. In the near-term, the impact assessment focuses upon utility projections, and is consistent among most scenarios. In the long-term, impacts are directly related to scenario policies that change the level of supply or its distribution within the region; or any component involved in defining site suitability. The comparison between such policies. The results may suggest either a change in scenario policies or the redefinition of siting issues.

SCENARIOS AND SITING POLICIES

Two basic groups of scenarios are considered (Table 3).[9] The first assumes that all scenario unit additions will use conventional technology, with coal as the primary fuel. No nuclear-fueled units are sited after 1985 except those that the utilities had announced in 1975. Scenario 2, which assumes high rates of economic growth, base case environmental control policies and other current conditions, including siting policies, is the point of reference for the coal-based scenarios. Whereas growth rate assumptions affect the number of scenario units that need to be added to projected additions, environmental controls and siting policies directly affect the geographical distribution of those units within the ORBES region. Scenarios 1a, 1b, 1c and 1d are specifically designed to assess the impacts of selected changes in environmental and siting policies within the context of strict environmental controls. In the case of Scenario 2a, additional scenario units that are dedicated to export electricity to the Northeast are located in the eastern part of the region.

The second group of scenarios emphasizes fuel substitution and conservation. Scenario 2c emphasizes nuclear-fueled capacity additions after 1985. Others assume that other fuels (Scenarios 3 and 4) or conservation (Scenario 6) will dominate energy supply in the long-term. These scenarios have the same environmental controls and siting policies as Scenario 2. The number of coal-fired scenario unit additions that are sited, however, differs significantly. In some cases, this has the effect of changing the schedule of on-line dates for electrical generating capacity additions.

Table 3. DESCRIPTION OF SCENARIOS AND SITING POLICIES[a]

Scenario	Technology	Primary Fuel 1986-2000	Growth Rates Energy	Growth Rates Economic	Environmental Control Policy	Siting Policy
1	Conventional	Coal		High	Strict	Strict
1a					Very stringent air quality	Dispersed
1b						Concentrated
1c					Agricultural lands protection	Dispersed
1d						Concentrated
2	Conventional	Coal		High	Base Case	Base Case
2d					Lax air quality standards	
2i					Once-through cooling for plants on Ohio River main stem	
2a			Coal-fired exports			Coal-fired exports
2a2					Once-through cooling for plants on Ohio River main stem	
2c	Conventional	Nuclear		High	Base Case	Base Case
2b			Nuclear-fueled exports			Nuclear-fueled exports
2b1					Once-through cooling for plants on Ohio River main stem	
3	Alternative	Alternative		High	Base Case	Base Case
4	Conventional	Natural Gas		High	Base Case	Base Case
5	Conventional	Coal		Low	Base Case	Base Case
5a				Very High		
6	Conventional	Coal	Very Low	High	Base Case	Base Case
7	Conventional	Coal	High	High	Base Case	Base Case
7a					Least emissions dispatch	

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[a] The basic scenarios are enclosed in boxes, followed by other scenarios that are derived from them in order to assess changes in impacts that might occur as the result of specific policy options. The policy options are specified in the descriptions of derivative scenarios.

FOOTNOTES

[1] The siting models developed by Argonne National Laboratory (1978) Brookhaven National Laboratory (Meier, 1977) and Oak Ridge National Laboratory (Davis et al, 1978) were used in the National Coal Utilization Assessment. The Argonne model incorporates previous work on SITE (Frigerio et al, 1975) whereas Oak Ridge used previous work for the Maryland Power Plant siting Program (Dobson, 1979).

[2] The Argonne model distinguishes coal-fired units by source of coal (e.g., in-state coal and imported high sulfur and low sulfur coal). A special siting pattern for Illinois is developed for a high energy growth scenario using Illinois coal. Coal gasification plants are sited in Illinois and Indiana, and coal liquifaction plants are sited in the region.

[3] Economic costs generally concern either coal transportation or electricity transmission, whereas population density is an indicator for 'social' impacts. Socioeconomic issues are not defined as a matter of resource use, technological constraints or regulatory decisions.

[4] This procedure is identical to the exclusionary screening and comparative evaluation procedures used by utilities except that the regions of interest and 'sites' are larger, and several technologies may be involved. See the discussion in Section 2.

[5] Contrary to the practice of other models, Eagles, Cohon and ReVelle (1979) include exclusionary criteria that are not used in comparative evaluation. Most are land use and ecological criteria.

[6] This is especially true of the ORNL model, which defines site suitability by a linear-weighted model. A large number of siting criteria are used to define the issues, and then are assigned weights that are intended to reflect different siting objectives (Dobson, 1969). Although these may be expected to reflect the values of different groups, only siting experts participated.

[7] Most models are deterministic in the sense that they assign new facilities to sites according to rank order on the site suitability scale. In the Utility Simulation Model (Van Horn, Liroff and Hirata, 1980), site (county) weights are converted into cumulative probabilities and generating unit additions are allocated by a Monte Carlo method.

[8] The ORNL model (Davis et al, 1978) also uses the maximum to redistribute 'excess' planned capacity when disaggregating energy supply scenarios. This creates an even more dispersed geography of energy supply in the long-term.

[9] The scenarios are discussed in detail in Page and Stukel (forthcoming).

SECTION 4

SCENARIO UNIT ADDITIONS AND SPATIAL ALLOCATION PROCEDURES

The energy and fuel demand model projects the total electricity production for each scenario, by fuel type, for the ORBES region in the year 2000. Generating units that are in service in 1975 supply a portion of the total production in each scenario. The number of additional coal-fired and nuclear-fueled generation units that is required to satisfy the incremental production from 1976-2000 is calculated on the assumption that it will be supplied by a combination of generating units for which utilities have announced on-line dates after 1975, and a sufficient number of standard generating units for the 1986-2000 period to account for the necessary capacity additions as well as the retirement of older units. The schedule of capacity additions also combines the announced utility plans with a linear schedule of the scenario units added after 1986.

Procedures for the geographical distribution of generating capacity additions at county scale also combines announced utility plans and scenario models. The locations of the announced capacity additions are generally known. The scenario unit additions, however, are allocated to counties within state subregions according to a procedure that takes into consideration their relative suitability as candidate sites for coal-fired and nuclear-fueled units.

CALCULATING SCENARIO UNIT ADDITIONS

A standardized procedure for calculating capacity additions for each scenario was used to determine the number of coal-fired and nuclear-fueled scenario unit additions that will need to be sited in each state subregion (Tables 4 and 5). Information on sited electrical generating capacity in 1975, and near-term (1976-1985) changes in capacity, are from the Electrical Generating Unit Inventory (EGUI) (Jansen, 1978). Sited capacity in 1985 is calculated by adding the 1976-1985 additions and removals (negative signs are for removals) to the 1975 capacity, according to electric utility plans announced at the end of 1976 and reported in the EGUI.

Sited capacity in the year 2000 is calculated by adding the 1986-2000 additions and removals to the 1985 figures, assuming an average useful life of 35 years for units that had no announced retirement dates. Because comprehensive data on planned capacity additions and removals were available only through 1986, the useful life of existing units was estimated from data in the EGUI. An analysis of actual and projected retirement dates in relation to on-line dates for electrical generating units in the study region indicated that units were retired after an average 35 years of on-line service.[1] Consequently, generating units that had no announced retirement date were removed after 35 years of service. Units that had an announced retirement date were allowed to remain in service until that date, and units that had neither an on-line date nor a retirement date were retired in 1985.

Table 4. METHODOLOGY FOR CALCULATING UNSITED ELECTRICAL GENERATING UNIT ADDITIONS

Worksheet Column Number	Title	Source or Method of Calculation
(1)	SUBREGION	ORBES portion of each state
(2)	FUEL	Coal (650 MWe siting increments) Nuclear (1000 MWe siting increments)
(3)	1975 SITED CAPACITY, MWe	Electrical Generating Unit Inventory (EGUI)*
(4)	1976-1985 SITED ADDITIONS, MWe	EGUI
(5)	1976-1985 REMOVALS, MWe	EGUI, assuming 35 year unit life
(6)	1985 SITED CAPACITY, MWe	(3) + (4) + (5) = (6)
(7)	STATE SHARE, %	$(\text{State MWe}_{1985}/\text{Total MWe}_{1985})_{C,N} \times 100 = (7)$
(8)	1986-2000 SITED ADDITIONS, MWe	EGUI
(9)	1986-2000 REMOVALS, MWe	EGUI, assuming 35 year unit life
(10)	2000 SITED CAPACITY, MWe	(6) + (8) + (9) = (10)
(11)	2000 SCENARIO x 10^{15} Btu	$(\text{Total})_C$ = 0.95 x fossil electric utilities production from energy and fuel demand model** $(\text{Total})_N$ = nuclear electric utilities production from energy and fuel model** $(\text{State})_{C,N} = (\text{Total})_{C,N} \times [(7)/100] = (11)$
(12)	2000 SCENARIO, MWe	For coal [(11)/1.49 x 10^{10} Btu/MWe] at 50% capacity factor For nuclear [(11)/1.94 x 10^{10} Btu/MWe] at 65% capacity factor
(13)	2000 UNSITED CAPACITY, MWe	(12) - (10) = (13)
(14)	2000 UNSITED UNITS, #	For coal (13)/650 MWe rounded to nearest integer For nuclear (13)/1000 MWe rounded to nearest integer
(15)	2000 RESIDUAL, MWe	For coal [(14) x 650 MWe] - (13) = (15) For nuclear [(14) x 1000 MWe] - (13) = (15)

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*Jansen (1978).

**Page, Gilmore and Hewings (1980).

Table 5. UNSITED ELECTRICAL GENERATING UNIT ADDITIONS

		1975	1976 - 1985		1985		1986 - 2000		2000					
										SCENARIO				
SUBREGION (1)	FUEL (2)	SITED CAPACITY MWe (3)	SITED ADDITIONS MWe (4)	REMOVALS MWe (5)	SITED CAPACITY MWe (6)	STATE SHARE % (7)	SITED ADDITIONS MWe (8)	REMOVALS MWe (9)	SITED CAPACITY MWe (10)	x 10^{15} Btu (11)	MWe (12)	UNSITED CAPACITY MWe (13)	UNSITED UNITS # (14)	RESIDUAL MWe (15)
ILLINOIS	Coal	10,512	4,399	-511	14,400	14.28	1,273	-3,631	12,042					
	Nuclear	1,865	4,056	—	5,921	54.7	—	-209	5,712					
INDIANA	Coal	10,114	8,951	-534	18,531	18.37	1,000	-5,272	14,259					
	Nuclear	—	2,260	—	2,260	20.9	—	—	2,260					
KENTUCKY	Coal	10,948	8,880	-837	18,991	18.83	2,150	-4,962	16,179					
	Nuclear	—	—	—	—	0.0	—	—	—					
OHIO	Coal	17,034	3,927	-1,438	19,523	19.35	—	-5,160	14,363					
	Nuclear	—	810	—	810	7.5	810	—	1,620					
PENNSYLVANIA	Coal	9,691	6,134	-336	15,489	15.36	—	-2,525	12,964					
	Nuclear	—	1,830	—	1,830	16.9	—	—	1,830					
WEST VIRGINIA	Coal	11,966	2,552	-582	13,936	13.82	—	-3,670	10,266					
	Nuclear	—	—	—	—	0.0	—	—	—					
TOTAL	Coal	70,265	34,843	-4,238	100,870	100.01	4,423	-25,220	80,073					
	Nuclear	1,865	8,956	—	10,821	100.0	810	-209	11,422					

[a] Column does not add to total due to rounding.

The ORBES energy and fuel demand model (Page, Gilmore and Hewings, 1980) provides the total regional electricity production for each scenario (Table 6, for example). The total production figures for the fossil electric utilities sector and the nuclear electric utilities sector are converted to quadrillion Btu's (quads).[2] Fuel-specific electric production totals in the year 2000 then were apportioned to state subregions according to the states' projected shares of electricity production in 1985. This procedure preserves the state subregions' relative rank in the region with respect to their use of coal and uranium as electricity generating fuels. It also assumes that Kentucky and West Virignia will not acquire nuclear-fueled generating capacity by the year 2000, as neither state had nuclear capacity planned for operation by 1985. Similarly, Illinois will maintain its lead in nuclear-fueled capacity because it had more than one-half of the region's nuclear capacity planned for 1985. The distribution of future coal-fired generating capacity was similarly apportioned. For example, Ohio is allocated the largest share of coal-fired capacity from 1985-2000 because it had more coal-fired capacity planned for 1985 than any other state subregion.

The scenario electric utilities production figures for the year 2000 are converted to megawatts (MWe) of generating capacity. The conversion takes into account the Btu's in a megawatt-hour of electricity (3.412×10^6 Btu/MWH); the number of hours in a year (8760 hr/yr); and the capacity factor (CF) of the generating equipment. Although the first two numbers are invariant, CF, which is defined as the ratio of the average load on a piece of generating equipment to the equipment's capacity rating, varies widely. Estimated CFs for coal-fired generating units in the region averaged 53.3% in 1976 and 50.9% in 1977. Nuclear-fueled units had CF's that averaged 54.7% in 1976 and 58.3% in 1977. Sample data for units in the region with capacities of 400 MWe or greater for 1967-1975 show a steady decline in CF's for coal-fired units from a range of 60-80% for state-wide values in 1967 to 40-60% in 1975 (USDOE, 1978). In systems that have a mixture of coal-fired and nuclear-fueled generation, the nuclear units commonly are loaded first and, consequently, have higher CF's than coal-fired units in the same system. Uranium is less expensive than coal on the basis of the energy content of the fuel, and nuclear-fueled generating equipment is more expensive than coal-fired equipment so it is to a utility's economic advantage to generate all the electricity it can from its nuclear units. Utility plans in the region indicate a trend toward a mixture of coal-fired and nuclear-fueled generation. Consequently, coal-fired scenario unit additions are assigned a CF of 50% and nuclear-fueled scenario unit additions are assigned a CF of 65%.

The conversion from quads of electricity production to MWe of generating capacity used conversion factors based on the Btu/MWH, hr/yr and the CF's. Thus, coal-fired capacity was the result of dividing the coal entries in Table 5, Column (11) by 1.94×10^{10} Btu/MWe. The total MWe of capacity needed to supply the electricity production that the scenarios project, less the sited capacity either in place or planned, is the unsited capacity that must be allocated to sites, according to some scheduling pattern, in order to assess the impacts in the long-term, i.e. from 1986-2000. This unsited capacity in each fuel type is then divided into a number of standard scenario unit additions. Coal-fired units are assigned a nominal electrical generating capacity of 650 MWe and nuclear-fueled units are assigned a nominal capacity of 1000

Table 6. 1974 BASELINE DATA, 1985 AND 2000 SCENARIO 1 SOLUTIONS TO THE ORBES ENERGY DEMAND MODEL (Sectors 1-24 are in Trillion Btu's while Industries 25-67 are in Millions of 1967 Dollars)

	final demand			total production			total consumption		
	1974	1985	2000	1974	1985	2000	1974	1985	2000
1 coal mining	0	0	0	10964	15254	20682	4842	6736	9133
2 crude petroleum, gas	0	0	0	663	722	703	5429	5738	5587
3 shale oil	0	0	0	0	0	0	0	0	0
4 gasified coal	0	0	0	0	0	0	0	0	0
5 solvent-refined coal	0	0	0	0	0	0	0	0	0
6 ref'd petroleum products	0	0	0	2107	2175	2319	3186	3267	3504
7 natural gas utilities	0	0	0	3302	3273	2975	2176	2157	1961
8 coal combined cycle elec.	0	0	0	0	0	0	0	0	0
9 fossil electric utilities	0	0	0	1074	1587	2233	814	1083	1692
10 nuclear elect. utilities	0	0	0	23	210	210	18	143	159
11 high-temp gas reactor	0	0	0	0	0	0	0	0	0
12 renewable elec. util's	0	0	0	13	35	35	10	24	27
13 ore-reduction feedstocks	0	0	0	215	282	390	215	282	390
14 chemical feedstocks	12	17	26	325	434	704	325	434	704
15 water transport	0	0	0	15	19	21	15	19	21
16 air transport	0	0	0	26	34	49	26	34	49
17 truck, bus transport	0	0	0	45	60	80	45	60	60
18 rail transport	0	0	0	17	22	33	17	22	33
19 auto transport	240	331	566	254	349	532	254	349	532
20 misc. thermal uses	0	0	0	1190	1542	2150	1190	1542	2150
//		//							//
61 real estate	9559	12543	20143	9487	12447	19193	14106	18507	28537
62 hotels, lodging, and amusements	1751	2298	3690	2895	3802	5754	3577	4699	7111
63 misc business and personal serv.	2201	2848	4639	3712	4878	7289	5615	6592	9849
64 advertising	22	29	47	1167	1562	2177	2215	2915	4061
65 auto repair	1072	1407	2259	1606	2112	3189	1679	2471	3731
66 medical and educational serv.	4630	6076	9757	4409	5786	9280	4754	6238	10005
67 nonprofit organizations	1298	1703	2735	1684	2210	3499	1493	1959	3102

SOURCE: Page, Gilmore and Hewings (1980, Appendix A, Table A.1).

MWe. These values are consistent with recent trends in utility unit size selection in the ORBES region.

PROJECTED ELECTRICAL GENERATING UNIT ADDITIONS FOR ORBES SCENARIOS

The number of unsited electrical generating units in each state subregion was obtained by dividing the unsited coal-fired (or nuclear-fueled, when appropriate) electric generating capacity by the nominal unit size, and rounding to the nearest integer. The number of unsited units calculated on the basis of state shares was adjusted to match the number of unsited units calculated for the regional total, as rounding errors sometimes resulted in discrepancies between the sum of the state subregions and the regional total. This adjustment minimized the residuals for each subregion subject to the constraint that the total residual for the region also be minimized.[3]

The projected number of coal-fired and nuclear-fueled scenario unit additions were calculated for each scenario (Table 7).[4] The final electric demand in the year 2000, and the choice of technology and fuel mix, are the principal determinants of the variations in the number of scenario unit additions. In Scenarios 2a and 2b, the assumption that additional generating capacity will be distributed according to state shares was changed according to policies related to the export of electricity to the Northeast. In Scenario 7a and in variations of those scenarios that have very strict environmental control policies, some of the coal-fired units assigned to Ohio are sited in other states. Otherwise, environmental controls do not affect the number of scenario unit additions or their distribution among the states.

SCHEDULE OF CAPACITY ADDITIONS

The schedule of on-line dates for capacity additions through 1985, and for the few units that are planned beyond 1985, is based upon announced utility plans. In most instances, the locations and tentative on-line dates for all planned additions are known. Although scheduling in the long-term is more difficult, the timing and order of plant construction for the additional units required to meet projected scenario demand in the year 2000 are necessary for impact assessment. The schedule chosen may be desireable for policy analysis, the base case should approximate utility behavior. Changes in the announced plans for near-term (i.e., 1976-1985) capacity additions should be minimized whereas the schedules for scenario unit additions post-1985 should follow the aggregate pattern for planned units in the region and the state subregions.

Scheduling new plant construction is an integral part of utility system planning (cf. Poldasek, 1977). Load forecast, reserve margins and the average size of electric generating units are the primary variables. If the reserve margin falls below the level considered necessary to meet projected peak loads, the utility may either purchase power from neighboring utilities or consider installing new capacity. If the utility decides to install new capacity, the schedule depends upon a projection of when the deficit in the reserve margin will occur, and the construction schedule of neighboring utilities. Employment scheduling is incorporated into the planning for capacity additions. Because reserve margins are a function of the size of units that a utility operates, larger utilities may install new capacity more frequently than smaller utilities.

Table 7. PROJECTED NUMBER OF COAL-FIRED AND NUCLEAR-FUELED ELECTRICAL GENERATING SCENARIO UNIT ADDITIONS TO BE SITED IN THE OHIO RIVER BASIN ENERGY STUDY REGION 1986-2000

State Subregion	Projected Number of Scenario Unit Additions, by Scenario and Fuel Type													
	1[a]	2[b]	2a[c]	2b[d]		2c		3	4	5	5a	6	7a	7b
	Coal	Coal	Coal	Coal	Nuclear	Coal	Nuclear	Coal	Coal	Coal	Coal	Coal	Coal	Coal
Illinois	13	13	13	13	1	4	19	9	4	10	17	2	20	18
Indiana	18	18	18	18	1	6	7	13	7	15	24	4	29	25
Kentucky	16	16	18	16	0	4	0	11	5	13	22	2	32	28
Ohio	20	20	33	20	10	8	2	14	8	17	26	6	32	32
Pennsylvania	14	14	19	14	8	4	5	9	4	11	18	2	18	16
West Virginia	14	14	25	14	0	6	0	10	6	12	19	4	28	25
Total Number of Units	95	95	126	95	20	32	33	66	34	78	126	20	159	144

[a] Scenarios 1a, 1b, 1c and 1d have the same number of scenario unit additions.

[b] Scenarios 2d and 2i have the same number of scenario unit additions.

[c] Scenario 2a2 has the same number of scenario unit additions.

[d] Scenario 2b1 has the same number of scenario unit additions.

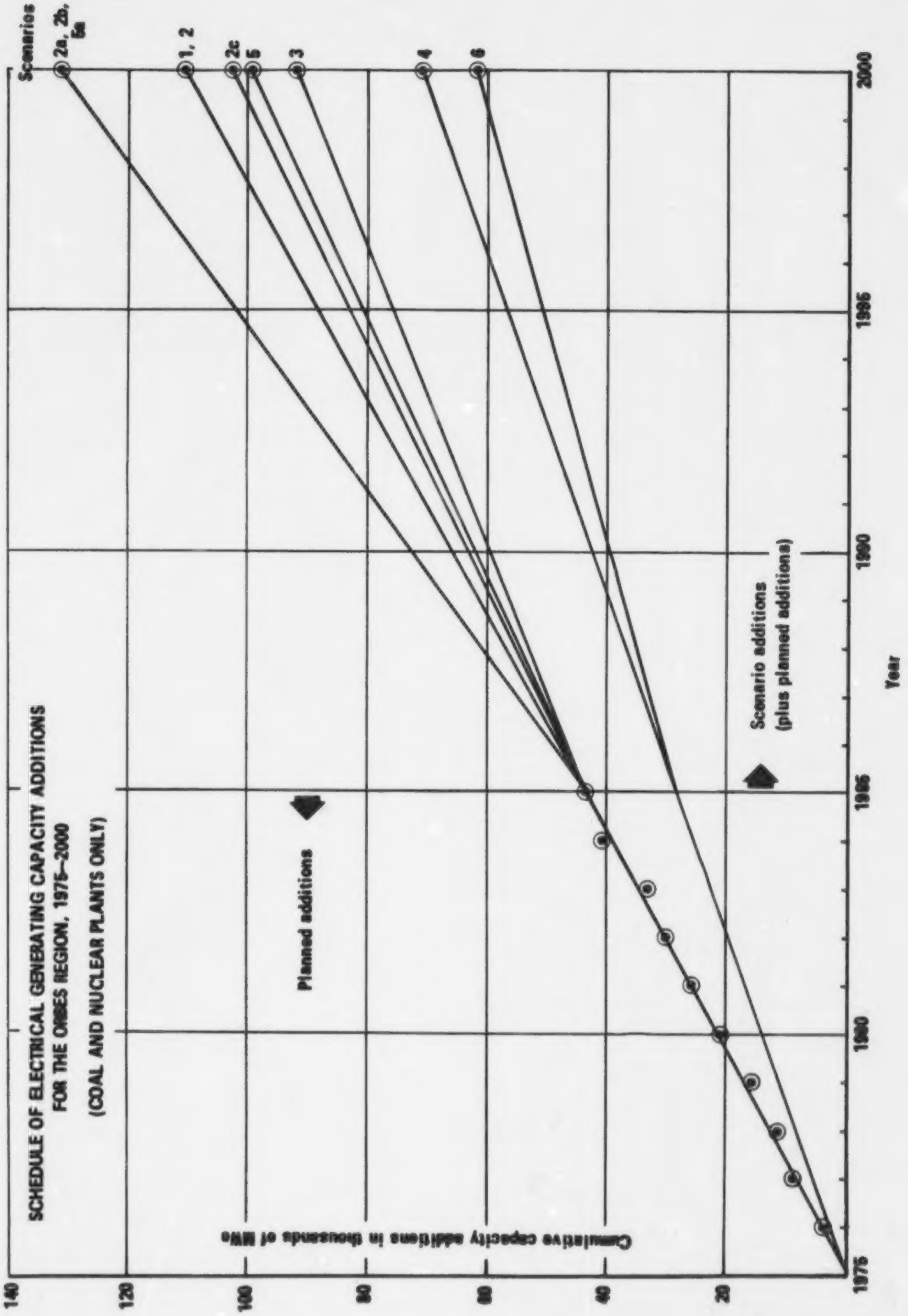
They will spread their construction commitments through time, although several units at the same site may be scheduled for consecutive years. They will also prefer to install new capacity within their service areas, although joint-ownership and a shortage of suitable sites are factors that a utility may consider in siting capacity additions in other service areas. Load forecasts are restricted to the demand in a utility's service area, whereas the location of the supply is becoming more flexible through arrangements such as joint ownership.

At regional scale, planned capacity additions, 1976 through 1985, are scheduled linearly with respect to time (Figure 10). The correlation is r = .99, with an estimated annual increment of 4,543 MWe. The schedules of planned cumulative additions for state subregions follow a similar pattern, although the strength of the relationship is slightly less in states that have smaller increments; e.g., Kentucky (r = .97), Ohio (r = .97) and Pennsylvania (r = .96). West Virginia has planned additions of only 2,552 MWe, with on-line dates of 1979 and 1980. The aggregate pattern, however, is unambiguously linear at regional scale and for five of the six states.

The schedule of on-line dates for capacity additions in the high electric energy growth scenarios combines announced utility plans, 1976-1985, with scenario unit additions distributed linearly from 1986-2000. Between 1975 and 1985, utility plans call for an additional 43,799 MWe of installed capacity in the ORBES region, for a 1985 total of 111,691 MWe (Table 8). The calculated annual increment of additions over the period 1977-1985 is 4,543 MWe for the high growth scenarios.[5] After 1985, the increment varies for each scenario, depending upon final electric demand in 2000. The low electric energy growth scenarios pose a special problem. In Scenario 6, the projected demand for electricity in the year 2000 is less than planned capacity for 1985. Scenario 4 final demand is only slightly more than that. Rather than prematurely retiring existing or planned generating units from service, the on-line dates of selected planned additions are delayed in order to conform to a linear pattern in which a single annual increment of additions is applied to the 1976-2000 period.[6] This assumes a pattern of slippage in the on-line dates of planned capacity additions similar to that observed in the region as utility plans are adjusted to lower projections of demand for electricity.

The growth curves of total installed electrical generating capacity for the ORBES region combine the schedule of planned additions through 1985, and linear additions for each scenario to the year 2000 (Figure 11). The ORBES region had 72,130 MWe of coal-fired and nuclear-fueled electrical generating capacity in 1975. Subsequently, the growth curves follow separate paths to 1985 capacities of 111,691 MWe for the high growth scenarios, and 96,387 MWe for the low growth scenarios. Beyond 1985, the curves diverge further in response to the differences in installed capacity additions that are necessary in order to supply the electrical energy demands that each scenario specifies for the year 2000. Except for scenarios 2a and 2b, 5a, and 7a and 7b, the slope of the installed capacity curves falls off smoothly toward the year 2000, primarily because of capacity retirements.

Figure 10



SCHEDULE OF ELECTRICAL GENERATING CAPACITY ADDITIONS FOR THE ORBES REGION, 1975–2000

(COAL AND NUCLEAR PLANTS ONLY)

Table 8. SCHEDULES FOR PROJECTED INSTALLED CAPACITY (MWe)
IN THE ORBES REGION FOR TWELVE SCENARIOS
(COAL AND NUCLEAR UNITS ONLY)

Scenario	Projected Capacity[a]		Annual Increments[b]		Cumulative Additions[c]	
	1985[c]	2000	1977-1985[d]	1986-2000	1976-1985	1976-2000
1	111,691	153,245	4,543	4,466	43,799	110,782
2		153,245		4,466		110,782
2a		173,395		5,809		130,932
2b		173,245		5,799		130,782
2c		145,295		3,936		103,832
3		134,395		3,209		91,932
4	96,387	113,595	2,843	2,843	28,495	71,132
5	111,691	142,195	4,543	3,729	43,799	99,734
5a		173,395		5,809		130,932
6	96,387	104,495	2,843	2,236	28,495	62,032
7a (35 yr. life)	111,691	178,372	4,543	7,239	43,799	152,382
7b (45 yr. life)				6,589		142,632

[a] Installed capacity in 1975 was 72,130 MWe.

[b] Rounding in annual increments creates small differences from figures shown when calculating cumulative additions.

[c] Planned capacity in 1985 was 111,691 MWe.

[d] Increment of 2,908 MWe used for 1976.

SPATIAL ALLOCATION PROCEDURES FOR SCENARIO UNIT ADDITIONS

States and portions of states that are in the ORBES region are the geographical units within which scenario unit additions are distributed. This choice of siting regions is consistent with the objectives of approximating current practices, and assessing policies at relevant geopolitical scales.

Electric utilities clearly prefer to locate generating capacity in their own service areas. This has the advantage of reducing transmission costs to load centers. However, utilities may also evaluate sites in adjacent service areas or elsehwere in their state, especially as the environmental and political constraints on siting new capacity additions increase. Locating new generating capacity in adjacent service areas, and entering into joint ownership agreements for capacity additions that may be located elsewhere, is limited primarily to planned additions.

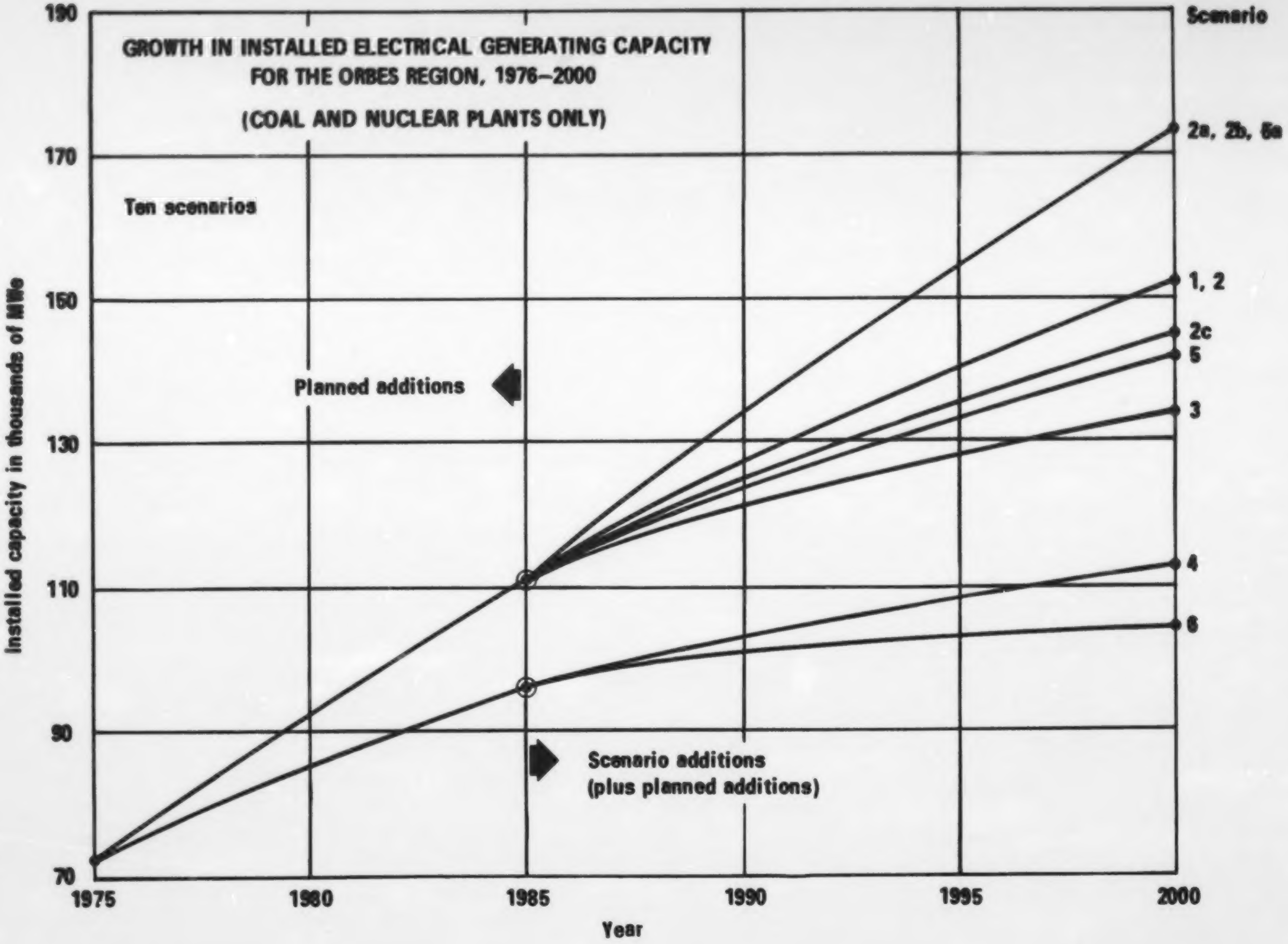
Furthermore, the state is the lowest level of government that has any significant regulatory control over the siting process. Public service commissions, siting authorities and other permitting agencies generally affect the location of new generating units within state boundaries and, except for a few cases, utility service area aboundaries coincide with state lines (Saper and Hartnett, 1980, p. 7). Federal agencies, such as the U.S. Environmental Protection Agency, have jurisdiction in selected areas that transcend state boundaries. Interstate commissions also may have some authority. However, their influence is at a larger geographical scale. The geographical allocation of scenario unit additions within state subregions can incorporate policies that reflect major subregional variations in resources that affect the suitability of counties as sites for new generating units.

Within a state or state subregion, the geographical distribution of electric generating capacity is specified at county scale. This is consistent with other regional assessment models, and offers a sufficient level of geographical detail for most types of impact assessment. The location of all existing units, and the county location of most planned additions, are known. For each scenario, the specified number of additional coal-fired and nuclear-fueled units are allocated to counties on state-by-state basis according to five general rules:

1. Scenario unit additions are allocated, by fuel type, two (2) units at a time, within each state or state subregion according to the rank order site suitability indices of the candidate counties.

    Coal-fired and nuclear-fueled units are treated separately, as counties may have different suitability indices for each fuel type because of their different resource requirements. Therefore, coal-fired and nuclear-fueled units may be located in the same or adjacent counties. Allocating two (2) units of each fuel type in a single siting decision is common utility practice, and consistent with ORBES scenario policies. Multiple units are usually scheduled for alternate years.

Figure 11



GROWTH IN INSTALLED ELECTRICAL GENERATING CAPACITY FOR THE ORBES REGION, 1976–2000

(COAL AND NUCLEAR PLANTS ONLY)

2. If two or more candidate counties in a state have the same site suitability index, the order of siting within the group is random. Siting proceeds within that group before scenario units are allocated to the county, or group of counties, with the next highest suitability index.

   Adjacent counties may share the same general resources. They may be approximately equally suitable as sites for new generating unit additions. This is common at the regional screening stage of site evaluation. However, relatively few counties in the ORBES region have the same site suitability indexes as defined by the ORBES siting model.

3. Scenario unit additions continue to be sited in the state subregion until the total number of units allocated to that state are located. A county may be selected more than once provided that its total sited electrical generating capacity (i.e., existing units, planned capacity additions and scenario unit additions) does not exceed 2600 MWe for coal-fired, and 4,000 MWe for nuclear-fueled units.

   The maxima, which are equivalent to four scenario unit additions of each fuel type, are consistent with utility guidelines. They allow for concentrations of electrical generation capacity in the most suitable counties, with both coal-fired and nuclear-fueled capacity in those counties that are highly suitable for either fuel type. The maxima can be increased to simulate a policy of "power parks" or "energy centers," or decreased to simulate a dispersed siting policy.

4. If there are scenario unit additions that cannot be sited in the state subregion to which they are allocated, this "excess" is sited in an adjacent state, or states, after the scenario unit additions assigned to that state, or states, have been sited.

   Adjacent states are defined as those having common boundaries.[7] The excess capacity is sited in the adjacent states according to their shares in the estimated electricity exports from the ORBES region in 1974 (Page, 1979, Appendix B). In effect, this simulates the common pattern of out-of-state partners in the joint ownership of recently constructed and planned large electrical generating unit additions in the ORBES region.

5. Scenario unit additions that cannot be sited in any state subregion will be located "outside" of the ORBES region.

   These units are not included in the impact assessment.

The allocation of scenario unit additions in several scenarios vary from the standard procedure in order to incorporate specific siting policies, or to reflect changes in policies that are inherent to the scenarios. These scenarios are:

Scenario 1a: Very Strict Air Quality Controls, Dispersed Siting
Scenario 1b: Very Strict Air Quality Controls, Concentrated Siting
Scenario 1c: Agricultural Lands Protection, Dispersed Siting
Scenario 1d: Agricultural Lands Protection, Concentrated Siting
Scenario 2c: Conventional Technology, Base Case Controls, Nuclear Emphasis

The procedures used in each are defined in subsequent sections. Also, Scenario 7: Conventional Technology, Base Case Controls, High Electricity Energy Growth, 35 Year Plant Life, as well as scenarios 1a and 1b have "excess" scenario units that are sited in adjacent states.

SITE SPECIFIC LOCATIONS FOR SCENARIO UNIT ADDITIONS

Certain impact assessment models require more specific locations for scenario unit additions. These include site-specific models of ecological and social impacts, as well as the models for calculating water quantity and quality impacts, especially for alternative power plant cooling systems. The exact locations of all existing and most planned capacity additions are known (Jansen, 1978). For scenario units that are added after 1985, the places at which the units might be located within a quarter county, if that county should be selected as a future site, are identified. Each quadrant of each candidate county was evaluated subjectively to determine "preferred" locations. Each quadrant was evaluated according to selected criteria. Those quadrants that border or are relatively close to a river; have small areas in public lands and few natural or unique areas; do not include large urban areas; are accessible to rail, road or water transportation; and have topographically suitable land sufficient for a scenario unit are preferred. Nonattainment areas for TSP and SO_2 are excluded, as are existing power plant sites that cannot accomodate additional units. In counties that have meager water resources, the preferred quadrants are those that have relatively large drainage areas exclusive of lakes and reservoirs most of which are associated with state parks and wildlife areas. In most instances, the preferred quadrants as well as the most plausible sites within them were readily identifiable.

FOOTNOTES

[1] Retirement age, or average useful life assumption, has important implications in calculating the number of generating unit additions that are necessary to meet projected final electric demand. As the useful life increases, the number of units that are required to meet a given level of demand decreases. The significance of these assumptions are analyzed in scenarios 7a and 7b, where air quality and fiscal impacts of meeting electric demand by increasing useful plant life from 35 to 45 years are compared.

[2] The fossil electric utilities production figure was corrected to remove the contribution from peaking units that generate electricity from natural gas and petroleum products. Peaking units contribute about five percent of the total fossil electric production in the region. The remainder is from coal-fired electricity generation.

[3] The residuals represent the difference between the number of scenario generating units to be sited and the amount of capacity specified in the scenario. The differences, which are the result of the fixed MWe size of scenario unit additions, are calculated by multiplying the scenario unit size by the number of unsited units and then subtracting the unsited capacity in Table 5, Column (13). A minus sign (-) in column (15) indicates that insufficient MWe has been sited; a plus sign (+) menas that more MWe capacity has been sited than the projected scenario demand.

[4] Tables that detail the calculations used in determining the number of scenario unit additions for each scenario are in: Fowler et al (1980).

[5] The cumulative additions are calculated by multiplying the annual increment by the number of years in the period, and adding the fixed increment of 2908 MWe for 1976.

[6] The annual increment was calculated for scenario 4 and then modified slightly for the period 1986-2000 to accomodate the lower energy growth rate of scenario 6. The on-line dates for planned additions through 1985 were rescheduled over the entire 1976-2000 period in scenarios 4 and 6.

[7] The adjacent states are:

Illinois : Indiana, Kentucky
Indiana : Illinois, Ohio, Kentucky
Kentucky : Illinois, Indiana, Ohio, West Virginia
Ohio : Indiana, Kentucky, West Virginia, Pennsylvania
Pennsylvania : Ohio, West Virginia
West Virginia: Ohio, Pennsylvania, Kentucky

SECTION 5

SITING ISSUES AND SITE SUITABILITY

The ORBES siting methodology includes a hierarchial linear weighted model for determining the suitability of counties as sites for standard coal-fired and nuclear-fueled capacity additions under different scenario policies. The siting criteria are defined in terms of the resource requirements of standard plants and the regulatory constraints included in the description of current, base case and strict environmental controls. These criteria are then assigned weights according to their relative importance to power plant siting in the ORBES region. The weights, which are based upon a Nominal Group Process technique exercise, are used to define site suitability indices for siting the scenario unit additions that, in addition to planned units, are needed to meet the total electricity production in the ORBES scenarios.

SITE SUITABILITY MODEL

The ORBES siting model includes five components, two of which are composed of several variables (Table 9). Each represents an issue of resource availability or regulatory constraint that is significant to siting coal-fired or nuclear-fueled electricity generating facilities in the ORBES region. The choice of issues, as well as the definition of primary variables used to determine site suitability, was the result of a review of the general process for siting coal-fired and nuclear-fueled generating units, in consideration of the resource base in the ORBES region and the policies of concern to the assessment.

Water availability and air quality are examples of components. The air quality component includes two variables, the maximum 24 hour ambient sulfur dioxide (SO_2) concentration ($\mu g/M^3$) and the maximum 24 hour ambient total suspended particulate (TSP) concentration ($\mu g/M^2$). Each of the variables used in the suitability formula are transformed or mapped onto a 0-10 scale. The minimum resource requirements of the standard plants and regulatory requirements are presented by these scores. Each variable within a component is then weighted on a scale of 0 to 1, and each component can have a weight of 0 to 10 according to its relative importance in the siting process.

Scenario policies that affect site suitability can be incorporated into the siting methodology by the choice of relevant components and variables as well as by the scores and weights assigned to them. For example, a policy that says that particulate concentrations are much more important than SO_2, and that water availability is of equal to air quality, could have a set of weights:

Table 9. DEFINITION OF PRIMARY VARIABLES USED IN DETERMINING SITE SUITABILITY

Issue	Fuel Type		Consideration	Measure	Criteria for Exclusion[a]	
	Coal	Nucl			Base Case Environmental Controls	Strict Environmental Controls
AMBIENT AIR QUALITY[b]						
	●		Reduction in pollutant concentrations	Location relative to nonattainment areas[c]	County designated nonattainment area, primary standard[d]	County contains nonattainment areas, primary and secondary standards
	●		Prevention of significant deterioration	Allowable increments as in PSD regulations	Majority of county in mandatory Class I area	Majority of county in mandatory Class I area
						Capacity additions exceed allowable increments (24 hr. max.)
WATER AVAILABILITY						
	●	●	Thermal pollution and acquision of cooling water	Low flow availability		
ECOLOGICAL SYSTEMS AND LAND USE						
	●	●	Natural, scenic and recreational areas	Extent of public lands	All of county in public lands[e]	Majority of county in public[f] lands
	●	●	Sensitive and protected environments	Unique natural areas		
	●	●	Agricultural and ecological productivity	Extent of Class I and Class II soils		
	●	●	Ownership and management of forest lands	Extent of non-federal forest		
HEALTH AND SAFETY						
		●	Radiation exposure	Population distribution		Population density ≥ 500 people per square mile[g]
		●	Seismic suitability	Distance from capable faults		Majority[h] of county in Seismic Zone III

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[a] The definition of exclusionary criteria varies according to scenario policies.

[b] According to the 1977 Clean Air Act Amendments.

[c] For SO_2 and TSP.

[d] _Federal Register_, 43, No. 43 (March 3, 1978): 8962-8853, and No. 194 (October 5, 1978): 45993-46019.

[e] Actual ownership.

[f] Total area, including designated purchase area.

$W_{SO_2} = W_{11} = 0.3$

$W_{TSP} = W_{21} = 0.7$

$I_1 = I_2 = 5$

The challenge is to relate policy statemnets to weights for those variables that are included in the definition of each scenario.

The mathematical description of the model follows:

C_{jk} = the absolute component index for the ith county and kth component.

W_{jk} = weighting factor for the ith criteria of the kth component.

X_{ijk} = numerical ranking for the ith criteria within the kth component for the jth county.

I_k = the importance of the kth component.

S_j = the absolute suitability index for the jth county.

S^{max} = the maximum suitability.

C_k^{max} = the maximum component index.

The equations that use these definitions to define site suitability are:

$$C_{jk} = \sum_{i=1}^{N_k} W_{ik} X_{ijk} \tag{1}$$

$$S_j = \frac{\sum_{k=1}^{M} I_k C_{jk}}{\sum_{k=1}^{M} I_k} \tag{2}$$

$$C_{jk}^{rel} = \frac{C_{jk}}{C_k^{max}} \; ; \; C_k^{max} = 10N_K \qquad (3)$$

$$S_j^{rel} = \frac{S_j}{S^{max}} \; ; \; S^{max} = \frac{10}{M} \Sigma_{k=1}^{M} N_k \qquad (4)$$

The domain for each of the parameters is:

$$0 \leq C_{jk} \leq C_k^{max}$$

$$0 \leq W_{jk} \leq 1 \text{ such that } \sum_{i=1}^{N_k} W_i = 1 \text{ for each } k$$

$$0 \leq X_{ijk} \leq 10$$

$$0 \leq I_k \leq 10$$

$$0 \leq S_j < S^{max}$$

This model combines exclusionary screening with a comparative evaluation of candidate sites for coal-fired and nuclear-fueled generating unit additions under different environmental control scenarios. It is similar to other base line assessment siting models, such as developed by ORNL (Davis et al, 1979). It differs from them in terms of its inclusion of a larger number of environmental variables, and its use in translating scenario policies into unique siting patterns for use in impact assessments.

SITING ISSUES

Ambient Air Quality

Ambient air quality is an issue of fundamental importance in siting coal-fired electrical generating units. Large coal-fired units are major stationary sources of air pollutant emissions, especially sulfur dioxide and particulate matter that is discharged as fly ash. They may contribute significantly to the deterioration of ambient air quality in regions where they are concentrated, or in distant areas affected by long-range pollutant transport. With respect to issues or ambient air quality, siting coal-fired generating units is subject to provisions of the Clean Air Act (42 U.S.C. 7400 et. seq.) applicable to stationary sources, and the attainment of National Air Quality Standards (NAAQS).

NAAQS are expressions of the allowable levels of concentration of specific pollutants in the ambient air. Currently, NAAQS have been established for six "criteria" pollutants: sulfur dioxide; particulate matter; carbon monoxide; photochemical oxidants; hydrocarbons; and nitrogen dioxide. The primary standard is that level necessary to protect the public health. The secondary standard is that level necessary to protect the public welfare from adverse effects of any pollutant. In cases where the standards for a pollutant differ, the secondary standard is always the most rigorous. Some provisions of the Act are designed to improve ambient air quality in places that do not meet the NAAQS, whereas others are designed to prevent deterioration of air quality in places that exceed the standards. Both are significant factors in siting new energy facilities.

A non-attainment area includes, for any pollutant, areas designated by the State, or any area that is shown by monitored data or air quality modeling, to exceed any ambient air quality standard for such pollutants (McHugh, 1978 and Grant, 1979). The object of the regulations for nonattainment areas is to improve ambient air quality by reducing emissions from existing sources and by severely restricting new source construction in or near the areas. An "emissions offset" policy applies to most major new construction or modifications of sources in nonattainment areas, including replacement of existing sources. In order to obtain a permit, the applicant must show that:

1. The new source achieves the "lowest achievable emission rate" (LAER) for that type source.
2. All of the company's existing sources in the region[1] are in compliance with their respective emission requirements.
3. Sufficient reduction of pollutants to be emitted are obtained from other sources in the region to more than offset the emissions from the new source.
4. The emission offset and the proposed new source emission levels will provide a net air quality benefit to the affected area, not just the region as a whole.

Regulations for the prevention of significant deterioration (PSD) govern new source construction in areas with ambient air quality that is equal to or better than that required by NAAQS (Table 10). Under the EPA regulatory scheme, these "clean air" areas are placed in one of three classes, each of which has maximum allowable increments of net air pollution increases for particulate matter (or, total suspended particulates--TSP) and sulfur dioxide (SO_2) permitted for each class up to a level considered significant for that area. The increments are based roughly on a percentage of the NAAQS for each pollutant. Thus, in Class I areas, ambient levels of TSP and SO_2 may be increased above the baseline concentration by an amount equivalent to about 2% of the NAAQS. Class II allows a 25% increase, and Class III a 50% increase. However, ambient air quality cannot exceed NAAQS in any case.

Certain Federal lands, national parks, wilderness areas, international parks and memorial parks are classified as mandatory Class I areas. They cannot be reclassified. Other clean air regions are in Class II. States have the authority to redesignate any area as Class I. Certain areas can be redesignated as Class III after public hearings and extensive review by state and federal agencies. In order to locate a major new source in a PSD area,

Table 10. SUMMARY OF CLEAN AIR ACT AMENDMENTS OF 1977, PREVENTION OF SIGNIFICANT DETERIORATION (PSD)

<table>
<tr>
<td>MAXIMUM ALLOWABLE
NON DETERIORATION INCREMENTS</td>
<td>
<table>
<tr><th rowspan="2">POLLUTANT</th><th colspan="3">MAXIMUM ALLOWABLE* CONCENTRATION INCREASE (ug/m^3)</th></tr>
<tr><th>CLASS I</th><th>CLASS II</th><th>CLASS III</th></tr>
<tr><td>SO_2 (3 HR)</td><td>25</td><td>512</td><td>700</td></tr>
<tr><td>SO_2 (24 HR)</td><td>8</td><td>91</td><td>182</td></tr>
<tr><td>SO_2 (ANNUAL)</td><td>2</td><td>20</td><td>40</td></tr>
<tr><td>PARTICULATE (24 HR)</td><td>10</td><td>37</td><td>75</td></tr>
<tr><td>PARTICULATE (ANNUAL)</td><td>5</td><td>19</td><td>37</td></tr>
</table>

. EXCEPT FOR THE ANNUAL VALUES, THE MAXIMUM ALLOWABLE INCREMENT CAN BE EXCEEDED ONCE PER YEAR.

. IT SHOULD BE NOTED THAT PSD CONCENTRATION INCREASES FOR CERTAIN AREAS ARE MANDATED AS CLASS I AS SHOWN IN THE NEXT BOX.

. OF SPECIAL IMPORTANCE TO UTILITIES IS THE IMPACT OF ANY FUTURE LEGISLATION NAMING NEW NATIONAL PARKS OR WILDERNESS AREAS. IF THESE PARKS OR WILDERNESS AREAS ARE LESS THAN 10,000 ACRES IN SIZE, THEY COULD CONCEIVABLY BE CLASSIFIED CLASS III. THOSE AREAS LARGER THAN 10,000 ACRES CAN ONLY BE CLASSIFIED AS CLASS I OR CLASS II. IT WOULD APPEAR ADVANTAGEOUS FOR UTILITIES TO PRESS FOR AREAS LESS THAN 10,000 ACRES IN ORDER TO GAIN OPTIONS OF CLASSIFYING PORTIONS OF REGIONS AS CLASS III.
</td>
<td>
. UPON DETERMINATION BY THE FEDERAL LAND MANAGER THAT THE AIR QUALITY IMPACT ON A FEDERAL CLASS I AREA IS ACCEPTABLE, A PERMIT COULD BE ISSUED ALLOWING CLASS I INCREMENTS TO BE EXCEEDED. THE MAXIMUM ALLOWABLE CONCENTRATION INCREASES ABOVE BASELINE FOR THIS CASE WOULD BE LIMITED AS FOLLOWS:

<table>
<tr><th>POLLUTANT</th><th>ALLOWABLE INCREMENT (ug/m3)</th></tr>
<tr><td>SO_2 (3 HR)</td><td>325</td></tr>
<tr><td>SO_2 (24 HR)</td><td>91</td></tr>
<tr><td>SO_2 (ANNUAL)</td><td>20</td></tr>
<tr><td>PARTICULATE (24 HR)</td><td>37</td></tr>
<tr><td>PARTICULATE (ANNUAL)</td><td>19</td></tr>
</table>

. A VARIANCE TO ONLY THE 3 HR AND 24 HR SO_2 STANDARDS APPLICABLE TO CLASS I AREAS CAN BE OBTAINED AFTER AN AFFIRMATIVE DEMONSTRATION TO THE GOVERNOR AND ACHIEVEMENT OF CONCURRENCE FROM THE FEDERAL LAND MANAGER. IN THIS EVENT, THE VARIANCE WOULD ALLOW THE EXCEEDANCE OF THE SO_2 STANDARDS FOR A PERIOD OF NOT MORE THAN 18 DAYS DURING ANY ANNUAL PERIOD. IN ADDITION, THE MAXIMUM ALLOWABLE INCREMENT WOULD BE LIMITED AS FOLLOWS:

<table>
<tr><th></th><th>ALLOWABLE LOW TERRAIN AREAS</th><th>INCREMENT (ug/m3) HIGH TERRAIN AREAS</th></tr>
<tr><td>SO_2 (3 HR)</td><td>130</td><td>221</td></tr>
<tr><td>SO_2 (24 HR)</td><td>36</td><td>62</td></tr>
</table>
</td>
</tr>
<tr>
<td>MANDATORY CLASS I
NON DETERIORATION AREAS</td>
<td colspan="2">
THE FOLLOWING AREAS ARE DESIGNATED AS CLASS I AND ARE NOT SUBJECT TO REDESIGNATION:
. INTERNATIONAL PARKS
. NATIONAL WILDERNESS AREAS > 5000 ACRES
. NATIONAL MEMORIAL PARKS > 5000 ACRES
. NATIONAL PARKS > 6000 ACRES WHICH EXISTED AS OF AUGUST 7, 1977
. ALL AREAS WHICH HAD BEEN REDESIGNATED CLASS I UNDER REGULATIONS EXISTING PRIOR TO THE CLEAN AIR ACT AMENDMENTS OF 1977
</td>
</tr>
<tr>
<td>VISIBILITY PROTECTION
PROVISION</td>
<td colspan="2">
. EPA MUST PROMULGATE REGULATIONS WITHIN 24 MONTHS TO ASSURE REASONABLE PROGRESS TOWARDS PREVENTING IMPAIRMENT OF VISIBILITY IN MANDATORY CLASS I FEDERAL AREAS.
. ALL ELECTRIC GENERATING UNITS WITH THE POTENTIAL TO EMIT 250 TONS OR MORE OF ANY POLLUTANT AND WHICH HAVE A HEAT INPUT MORE THAN 250 MILLION BTU'S/HR ARE AFFECTED BY THE VISIBILITY PROVISION.
. ELECTRIC GENERATING STATIONS WHICH HAVE A CAPACITY LESS THAN 750 MW'S AND WHICH HAVE BEEN IN OPERATION FOR MORE THAN 15 YEARS AS OF AUGUST 7, 1977, ARE EXEMPTED FROM THE REQUIREMENTS OF THE VISIBILITY PROVISION.
. EPA WILL PROMULGATE REGULATIONS DIRECTLY APPLICABLE TO ELECTRIC GENERATING UNITS HAVING A CAPACITY IN EXCESS OF 750 MW.
. IN DETERMINING BOTH "REASONABLE PROGRESS" TOWARDS ELIMINATING VISIBILITY IMPAIRMENT AND "BEST AVAILABLE RETROFIT TECHNOLOGY" THE ADMINISTRATOR MUST CONSIDER FACTORS SUCH AS COST, NON-AIR QUALITY ENVIRONMENTAL AND ENERGY IMPACTS, THE REMAINING USEFUL LIFE OF THE SOURCE AND, AS APPROPRIATE, THE DEGREE OF IMPROVEMENT IN VISIBILITY WHICH MIGHT BE EXPECTED.
</td>
</tr>
<tr>
<td>PSD - PERMIT PROGRAM
REQUIREMENTS</td>
<td colspan="2">
. THE LAW STATES THAT NO MAJOR EMITTING FACILITY CAN BE CONSTRUCTED AFTER AUGUST 7, 1977 UNLESS, A PERMIT ASSURING COMPLIANCE WITH PSD REQUIREMENTS, IS OBTAINED FROM THE EPA OR STATE, WHICHEVER IS APPROPRIATE.
. THE PERMIT APPLICATION MUST INCLUDE 1 YEAR'S WORTH OF AMBIENT AIR QUALITY MONITORING DATA UNLESS A WAIVER ALLOWING A SHORT PERIOD OF FIELD DATA IS OBTAINED FROM THE STATE.
. THE APPLICANT MUST DEMONSTRATE THAT EMISSIONS FROM CONSTRUCTION OR OPERATION OF THE PROPOSED FACILITY WILL NOT RESULT IN CONTRAVENTION OF NATIONAL AMBIENT AIR QUALITY STANDARDS, MAXIMUM ALLOWABLE NON-DETERIORATION INCREMENTS AND ANY OTHER APPLICABLE EMISSION STANDARD OR STANDARD OF PERFORMANCE. IN ADDITION, THE APPLICANT MUST DEMONSTRATE THAT: (1) THE BEST AVAILABLE CONTROL TECHNOLOGY IS BEING EMPLOYED, (2) THE FACILITY EMISSIONS ARE COMPLYING WITH ALL REQUIREMENTS RELATED TO MANDATORY CLASS I AREAS, AND THAT (3) AN ANALYSIS OF THESE POTENTIAL AIR QUALITY IMPACTS ASSOCIATED WITH GROWTH RELATED TO THE FACILITY HAS BEEN PERFORMED.
. EPA WILL BE PROMULGATING REGULATIONS REGARDING ACCEPTABLE AIR QUALITY MODELS FOR USE IN THE REQUIRED DISPERSION ANALYSES.
. A HEARING MUST BE HELD REGARDING THE PERMIT APPLICATION, AT WHICH TIME THE POTENTIAL AIR QUALITY IMPACTS, CONTROL TECHNOLOGY, ALTERNATIVES AND OTHER APPROPRIATE CONSIDERATIONS CAN BE RAISED.
. A PERMIT MUST BE GRANTED OR DENIED WITHIN ONE YEAR AFTER THE DATE OF FILING A COMPLETED APPLICATION.
</td>
</tr>
<tr>
<td>OTHER POLLUTANTS</td>
<td colspan="2">
. IN ADDITION TO THE NON-DETERIORATION INCREMENTS FOR SO_2 AND PARTICULATES, THE EPA IS MANDATED TO CONDUCT A STUDY AND WITHIN 2 YEARS TO PROMULGATE REGULATIONS TO PREVENT THE SIGNIFICANT DETERIORATION OF AIR QUALITY ASSOCIATED WITH EMISSIONS OF: HYDROCARBONS, CARBON MONOXIDE, PHOTOCHEMICAL OXIDANTS, AND NITROGEN DIOXIDE.
. EPA MUST ALSO PROMULGATE NON-DETERIORATION REGULATIONS FOR ANY OTHER POLLUTANT FOR WHICH IT ESTABLISHES NATIONAL AMBIENT AIR QUALITY STANDARDS.
</td>
</tr>
</table>

SOURCE: Envirosphere Company (1977).

the applicant must undergo a review for SO_2 and TSP to demonstrate that emissions from the new source will not exceed the allowable increments in that particular area as well as adjacent areas.

Although nonattainment and PSD provisions apply to specific geographical areas, the boundaries are not absolute with respect to the review processes (cf. McHugh, 1978). A new source that wishes to locate in a nonattainment area, for example, might, in addition to obtaining an emissions offset, also need a PSD permit if the air quality in adjacent clean air regions might be adversely affected in any way. Conversely, a new source that wishes to locate in a clean air region might, in addition to a PSD permit, be required to obtain an emissions offset if air quality modeling indicates that it will impact at all on the nonattainment area. An additional constraint in the PSD regions is the visibility impairment provisions, which are directed at eliminating and preventing any impairment of visibility in the mandatory Class I areas. The effect is to add a buffer zone to the Class I areas. The geographical range that may be used in the review procedures may be extensive. It may also involve extraterritorial sources, in which case provisions governing the prevention of interstate air pollution apply. These require a State to prohibit any new or existing source from emitting pollutants that would interfere with the attainment or maintenance of any NAAQS in a neighboring state. Thus, whether a source locates in a nonattainment area or PSD region, it must meet standards to prevent impact upon ambient air quality of neighboring areas, as well as interstate impacts.

The Clean Air Act has introduced considerable "uncertainty" into the siting of coal-fired electrical generating facilities (Grant, 1979). Nonattainment provisions make it diffucult to locate new units near major load centers, as most such centers are in industrialized urban and metropolitan areas that do not meet NAAQS. They also frequently have relatively small coal-fired units that were built prior to 1970, and that are not likely to be replaced by new units when they are retired. The nonattainment policy is a fairly stringent land control measure for all types of new developments, including energy facilities.

States in the ORBES region have tried to limit nonattainment areas to the smallest geographical units possible. Nonattainment areas for SO_2 and TSP in Illinois and Indiana, for example, are drawn along township lines or other minor civil divisions (Grant, 1978; Illinois Power Company, 1979). Although the geography of the nonattainment areas across the ORBES region varies considerably, two trends are apparent:

1. The number and size of nonattainment areas for TSP are greater than for SO_2.
2. The number and size of nonattainment areas increases from west to east, and north of the Ohio River.

These reflect a combination of actual pollutant concentrations as well as methods used to define nonattainment areas.[2]

Most new and proposed coal-fired generating units are sited in PSD areas. Although it is easier to obtain a PSD permit than to locate in nonattainment areas, the constraints are considerable nonetheless. Class I areas and surrounding areas are virtually excluded as sites. Coal-fired units must locate at some distance from the boundaries of Class I areas, although the exact distance will depend on meteorology and terrain. The provisions for visibility protection promise to extend the buffer zone. The ORBES region only has four mandatory Class I areas. Two are in Kentucky (Mammoth Cave National Park, Edmonson County; and Beaver Creek National Wilderness Area, Menifee County) and two are in West Virginia (Otter Creek National Wilderness Area, Randolph County; and Dolly Sods National Wilderness Area, Tucker County).

However, a large number of Class II areas are potential candidates for redesignation to Class I. The Shawnee National Forest and Crab Orchard Wildlife Sanctuary in southern Illinois are examples (Grant, 1979). In addition to increasing the geographical extent of Class I areas, they could restrict sites for coal-fired plants in coal-producing areas where mine-mouth locations might be desirable.

PSD policies also constrain the number and size of coal-fired units in Class II areas. An ANL study (Garvey et al, 1978) concludes that a maximum of 2700 MWe can be located at one site in flat or moderate terrain in Class II areas. Unit size may be reduced in rugged terrain, such as Appalachian Kentucky and West Virginia, where emissions will be trapped. The maximum allowable increments also raise the question of separation distances, as well as the optimum geographical distribution of coal-fired units within Class II areas (Equitable Environmental Health, 1976; Envirosphere, 1978). Issues of proximity may be especially critical where state boundaries are along the Ohio River and its major tributaries. The concentration of new sites in Boone County, Kentucky and Switzerland County, Indiana has resulted in a dispute over the PSD permit for the Indianapolis Power and Light Company's (IPALCO) Patriot plant. Where PSD provisions apply, applicants must ensure that increments will be available during the construction period. Other disputes concerned with the interstate pollution provisions of the Clean Air Act involve Ohio, Pennsylvania and West Virginia.[3]

Air quality issues are represented in the siting model with respect to the nonattainment and PSD provisions of the Clean Air Act for SO_2 and TSP. Nonattainment provisions are considered as exclusionary criteria. Depending on environmental control policies, counties are excluded from consideration as candidate sites if they contain, or are designated, nonattainment areas for any standard. This is consistent with current siting practice in the ORBES region, and with the difficulty of constructing new sources in nonattainment areas. PSD Class I areas are also excluded as sites because of the small allowable increment. Siting coal-fired generating units in the Class I areas is unlikely, and locating relatively close to them may even be difficult. The extent of the areas excluded for nonattainment areas and PSD Class I areas indirectly accounts for buffer zones, separation distances and other aspects of location relative to attainment and nonattainment areas.

The suitability of other counties as sites for coal-fired units is based on estimates of the increment of clean air that remains after a standard coal-fired scenario unit addition is sited (Figure 12). Given the NAAQS or whatever limit is allowed by law, the clean air increment is the amount that remains after the pollutants associated with a scenario unit addition are added to the background ambient concentrations in a county. Each county is then a score on a scale of 0 to 10, with all pollutant levels normalized to a base of 10 depending on the concentration limits allowed by law. As PSD Class I areas are excluded, all counties that are assigned suitability scores for the air quality component are in PSD Class II regions.

Average annual ambient concentrations for each pollutant represented the state of air quality in an area (county) before a scenario unit addition was sited. These baseline concentrations were estimated from monitoring data for each ORBES state subregion for 1977.[4] For counties that had no monitor, the ambient concentration was estimated using either a geographically weighted, linear interpolation between monitoring stations or simply the concentration in an adjacent county. The ambient concentrations after siting a scenario unit addition was then estimated, taking into consideration persistent wind conditions for five meteorological subregions and a calculational model consisting of the Guossian model (Kark and Warner, 1976) and the plume rise models of Holland, TVA-Concurve and Briggs.[5] The maximum concentration was calculated for each subregion for stability classes B, C, D, E and F. The worst case was selected for each subregion.

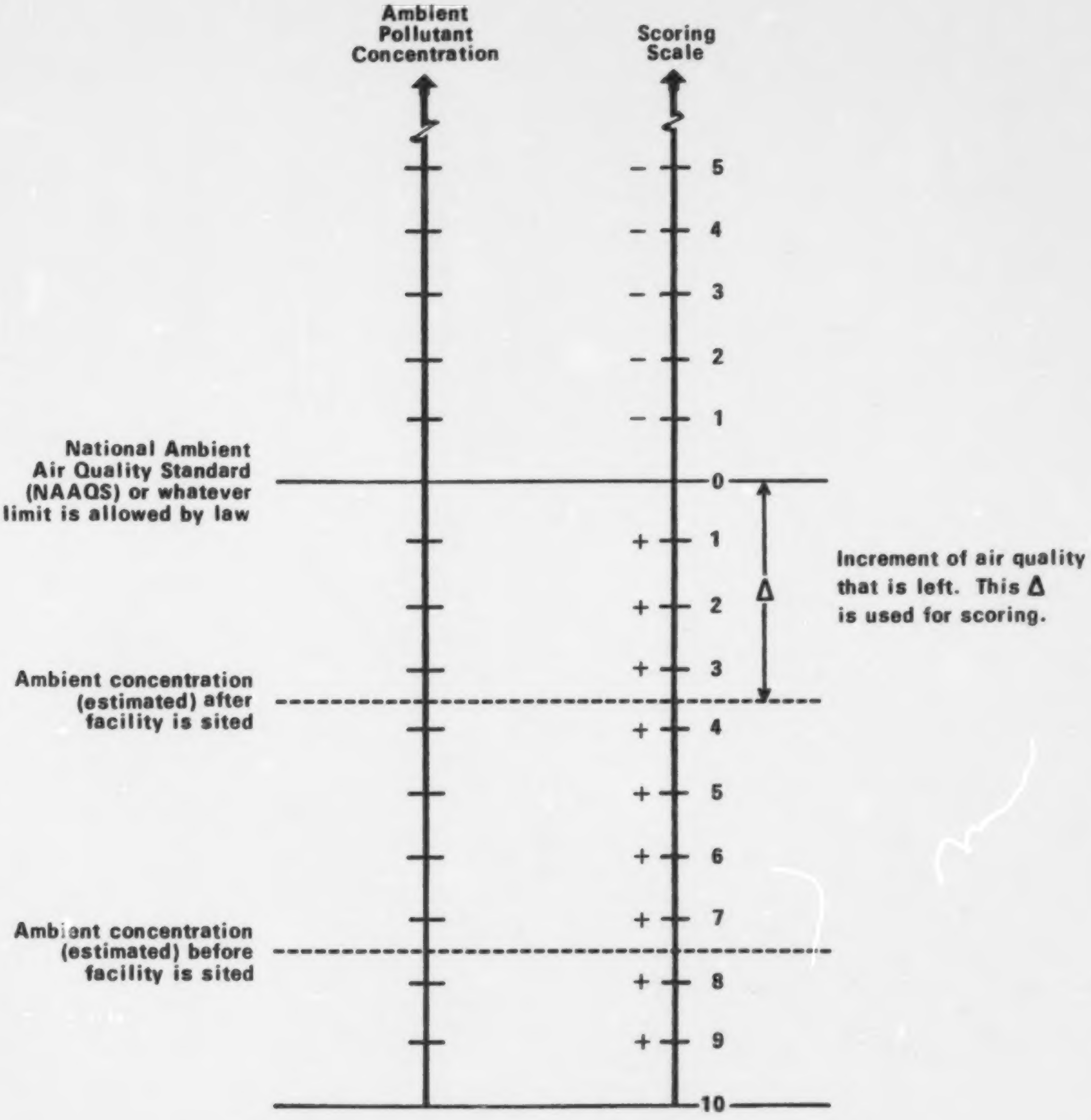
The increment of air quality that remain is used to score a county for each pollutant (Table 11). If the ambient concentrations that exist after a unit is sited exceeds NAAQS (or whatever the law allows), the Δ is negative. Counties with negative scores are excluded from consideration. If standards are not violated, the Δ is positive. In general, the larger the positive Δ the more suitable the county with respect to air quality. State standards are used as the ambient concentrations allowed by law. Primary standards are used for base case environmental control scenarios and secondary standards for strict environmental controls.

Site Suitability: Ambient Air Quality

In base case environmental control scenarios, the majority of the ORBES region has relatively high suitability scores with respect to SO_2 (Figure 13). Counties in western Pennsylvania and the West Virginia panhandle have the lowest score; i.e., the smallest allowable increment of clean air. Elsewhere, the only other areas that have some problems with SO_2 are in northeastern Ohio, southern Illinois and selected metropolitan regions (e.g., Indianapolis and Terre Haute, Indiana; Louisville, Kentucky; Cincinnati, Ohio; and Charleston, West Virginia). Compared with SO_2, however, TSP contributes more to low suitability with respect to air quality (Figure 14). The majority of the ORBES region has low suitability scores. The lowest are in western Pennsylvania, southeastern Kentucky and in the East St. Louis metropolitan area. The distribution of the scores, however, suggests that TSP is a much more ubiquitous pollutant than SO_2.

Because secondary standards are used for strict environmental control scenarios, the suitability scores decrease and cover a larger number of counties. Western Pennsylvania counties continue to have the lowest suitability with re-

Figure 12. **A SCHEME FOR SCORING A SITE IN TERMS OF AIR QUALITY**


Ambient Pollutant Concentration
Scoring Scale
– 5
– 4
– 3
– 2
– 1
National Ambient Air Quality Standard (NAAQS) or whatever limit is allowed by law
0
+ 1
+ 2
+ 3
Δ
Increment of air quality that is left. This Δ is used for scoring.
Ambient concentration (estimated) after facility is sited
+ 4
+ 5
+ 6
+ 7
Ambient concentration (estimated) before facility is sited
+ 8
+ 9
10

Note: A score of 10 implies no pollutant concentration. A score of <0 implies other sources of pollutant must be curtailed before facility is sited.

Table 11. DEFINITION OF THE AIR QUALITY COMPONENT

$$
\begin{aligned}
C_{j1} &= 1/3 \quad (X_{1j1} - \Delta_S) + (X_{2j1} - \Delta_{TSP}) + X_{3j1} \\
&= \overline{\lambda}\ 1/3\ (\Delta_S + \Delta_{TSP}) + 1/3\ (X_{1j1} + X_{2j1} + X_{3j1}) \\
&= -K_\Delta + 1/3\ (X_{1j1} + X_{2j1} + X_{ij1}) = -K_\Delta + C_{j1}
\end{aligned}
$$

Illinois : $\Delta_S = 1.84$, $\Delta_{TSP} = 0.2$, $-K_\Delta = -0.68$.*

Pennsylvania : $\Delta_S = 1.84$, $\Delta_{TSP} = 0.2$, $-K_\Delta = -0.68$.*

Ohio : $\Delta_S = 2.58$, $\Delta_{TSP} = 0.2$, $-K_\Delta = -0.93$.*

West Virginia: $\Delta_S = 1.84$, $\Delta_{TSP} = 0.2$, $-K_\Delta = -0.68$.*

Kentucky : $\Delta_S = 1.84$, $\Delta_{TSP} = 0.2$, $-K_\Delta = -0.68$.*

---

*After a scenario unit is sited, the Δ for air quality is decreased by a fixed amount for each unit added. The Δ's are constant values for a scenario unit addition located in the meteorological subregions of the ORBES region.

Figure 13. **PREVENTION OF SIGNIFICANT DETERIORATION**

SULFUR DIOXIDE (SO_2)

BASE CASE ENVIRONMENTAL CONTROLS

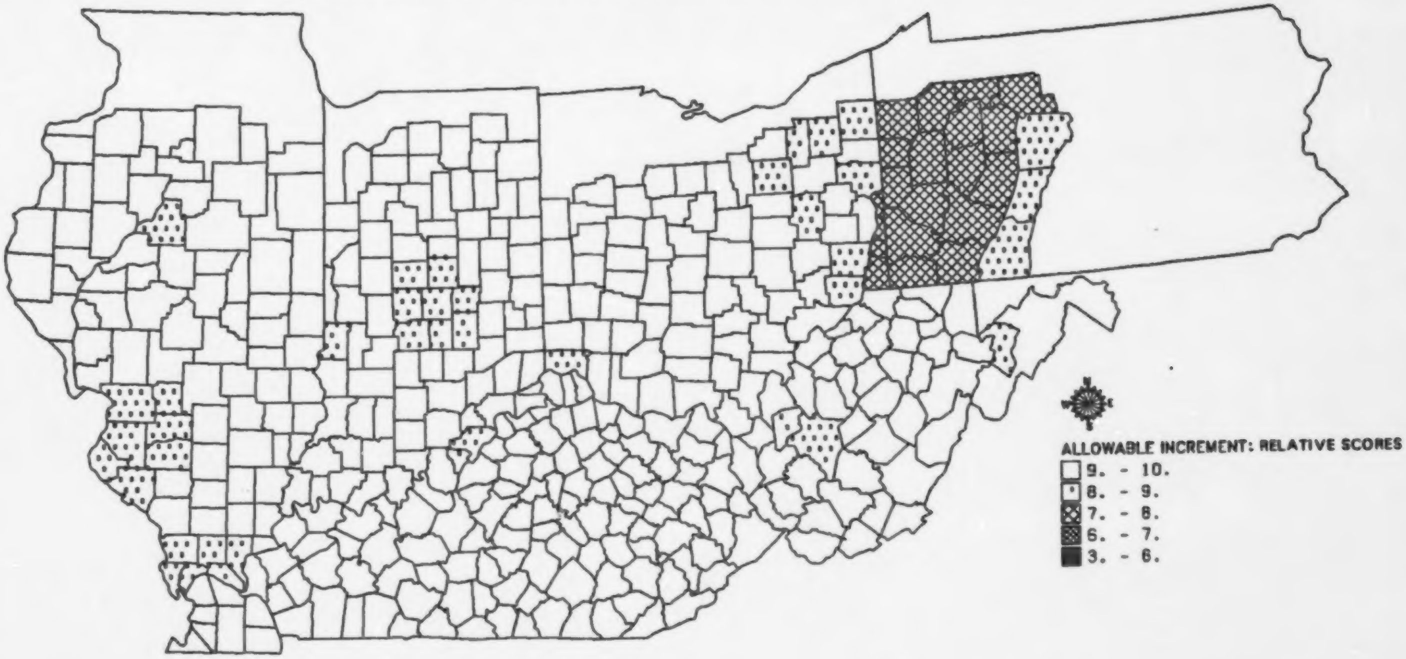


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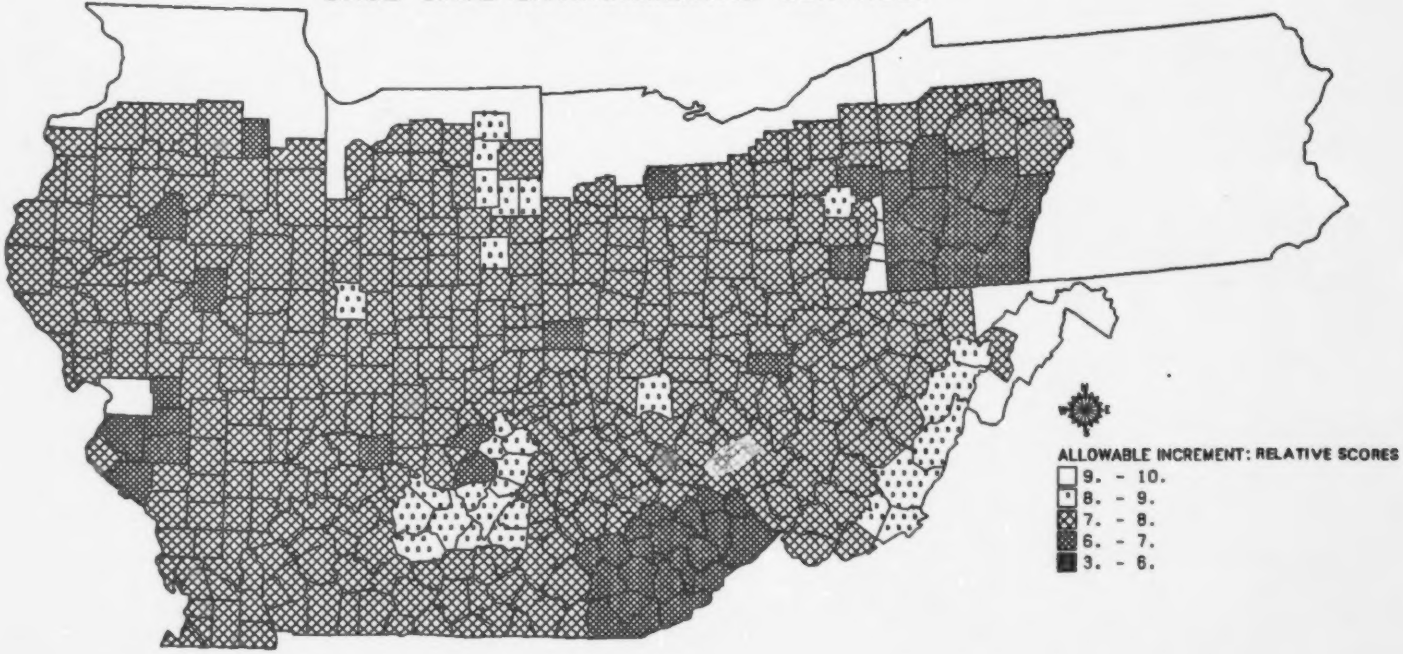
Figure 14. **PREVENTION OF SIGNIFICANT DETERIORATION**

TOTAL SUSPENDED PARTICULATES (TSP)

BASE CASE ENVIRONMENTAL CONTROLS



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spect to SO_2 (Figure 15). The range of counties with less than the maximum scores, however, expands to include large parts of eastern Ohio and West Virginia; central and southern Indiana; and southern and west central Illinois. However, TSP continues to be the dominant pollutant (Figure 16). The majority of the counties in the ORBES region are in the lowest suitability category. These include areas of intensive agriculture, coal mining and the major metropolitan industrial areas.

SO_2 and TSP are of equal importance in determining the suitability of counties as sites for coal-fired generating unit additions with respect to the ambient air quality component. In base case environmental control scenarios, all of the counties in the ORBES region have medium to high suitability (Figure 17). Western Pennsylvania and a few scattered counties, or groups of counties, have medium-high suitability. Most are counties that have some problem with both SO_2 and TSP. Elsewhere, concentrations of TSP are primarily responsible for reducing suitability scores. In the strict environmental control scenarios, the general effect of secondary standards is to reduce the suitability scores by at least one class (Figure 18). Selected areas are even less suitable. These include the Pittsburgh metropolitan area; most other metropolitan areas with relatively high SO_2 background concentrations; and a block of counties in west central Illinois with relatively high TSP concentrations.

Water Availability

Conventional methods of generating electricity from either coal or nuclear fuel require large quantities of water. These methods are based on the steam-electric cycle in which heat from the combustion of coal or from the fission of uranium is used to heat water to steam. The steam is expanded through a turbine which drives a generator to produce electricity. Closure of the steam-electric cycle is accomplished by condensing the steam to liquid water for recirculation back through the system. A relatively small amount of water is required as the working fluid but large quantities are needed as cooling water to condense the steam. In fact, the cooling water requirements are so large in comparison to the working fluid requirements that the latter may be neglected for siting purposes without significantly affecting the result.

The amount of water required for a site depends on the fuel type of the generating units, the number and size of the units, and the cooling technology. Each of these variables is prescribed within narrow limits for the ORBES scenarios. Except for certain variations on the base case scenario that allow once-through cooling on the Ohio River main stem, cooling technology is limited to wet (evaporative) cooling towers. This is in accordance with USEPA regulations and guidelines (CFR 40, Part 423) issued in 1974 to implement the 1972 Amendments to the Federal Water Pollution Control Act. These regulations designate closed-cycle cooling (cooling towers) as "best available technology" for control of thermal effluents. Reynolds (1980) gives further details on the history and implications of these regulations.

Nuclear-fueled generating units require considerably greater amounts of cooling water than coal-fired units. The difference is attributable to the

Figure 15. **PREVENTION OF SIGNIFICANT DETERIORATION**

SULFUR DIOXIDE (SO_2)

STRICT ENVIRONMENTAL CONTROLS

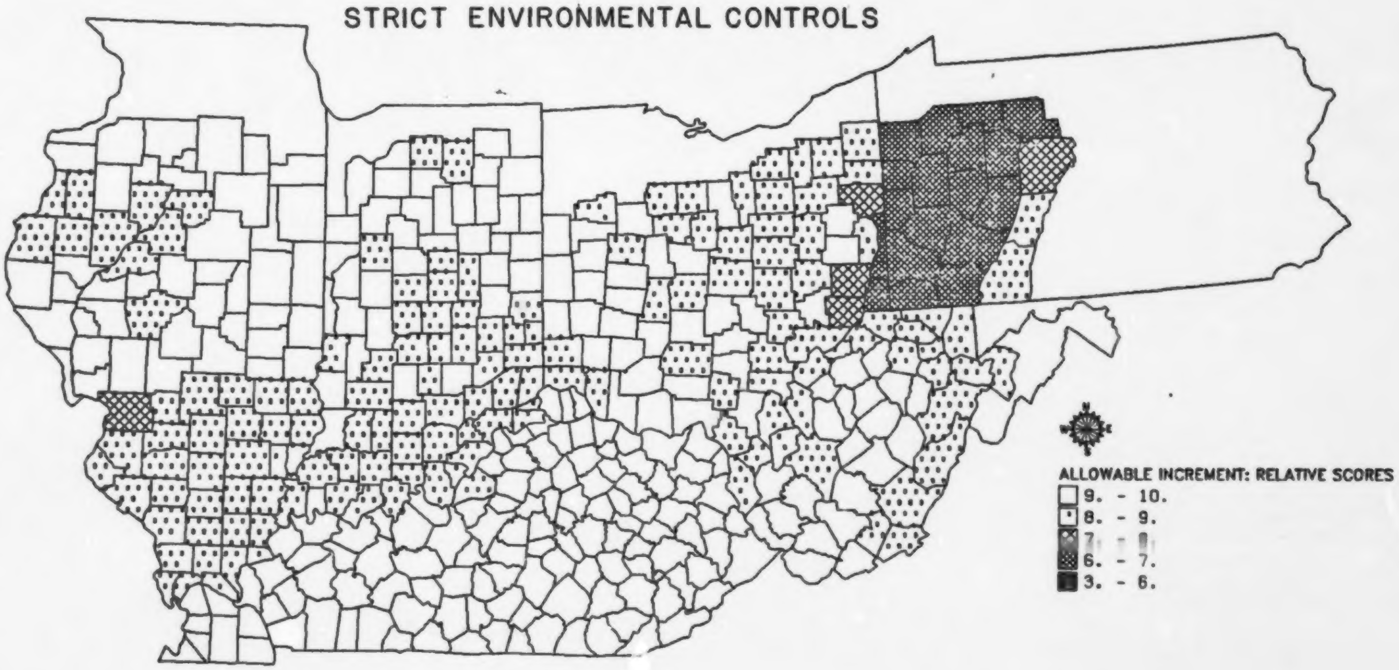

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Figure 16. **PREVENTION OF SIGNIFICANT DETERIORATION**

TOTAL SUSPENDED PARTICULATES (TSP)

STRICT ENVIRONMENTAL CONTROLS

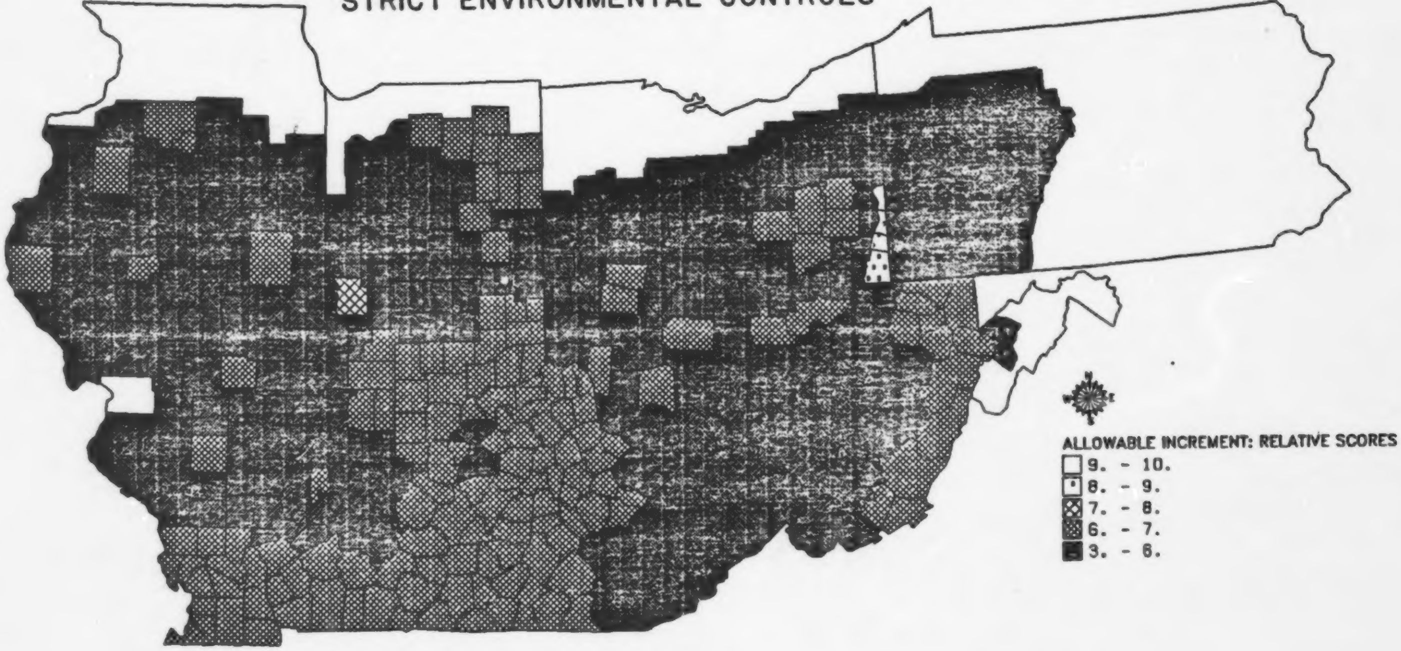

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Figure 17. **AMBIENT AIR QUALITY COMPONENT**

BASE CASE ENVIRONMENTAL CONTROLS

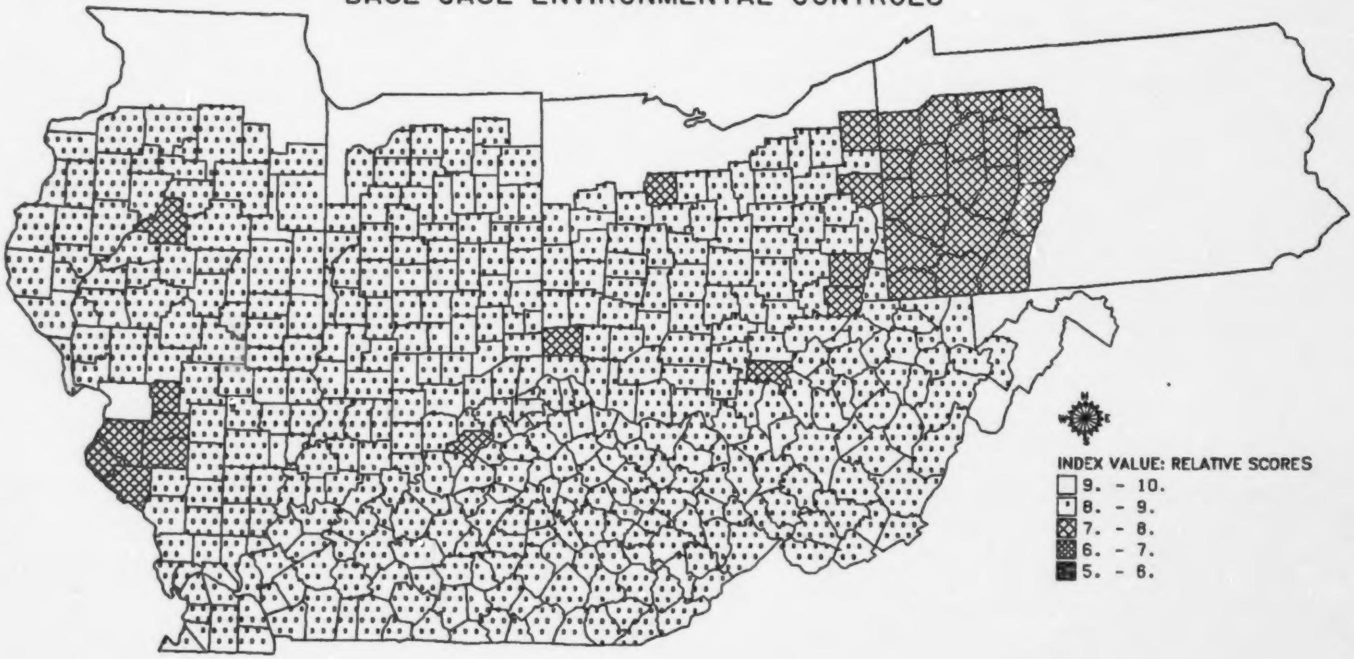

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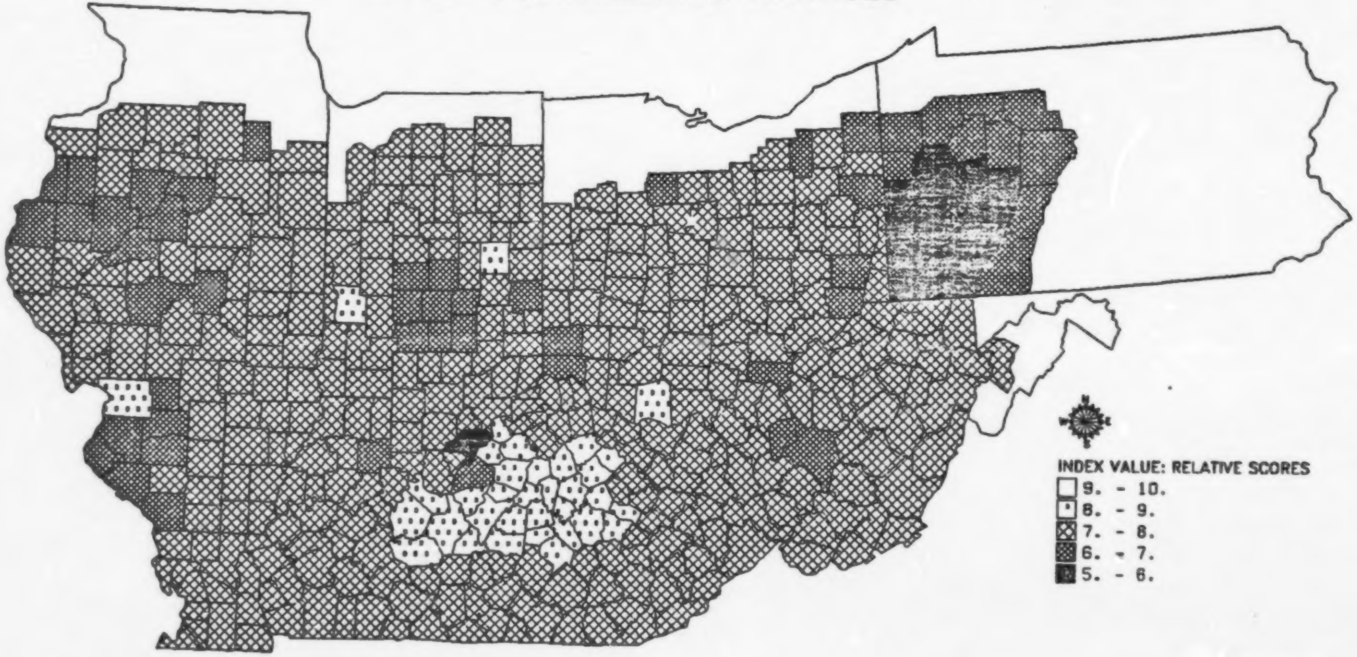
Figure 18. **AMBIENT AIR QUALITY COMPONENT**

STRICT ENVIRONMENTAL CONTROLS



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typically higher thermal conversion efficiency of coal-fired units (38% efficiency) compared with that of nuclear-fueled units (33% efficiency) and the fact that coal-fired units generally release 15 to 20% of their waste heat directly to the atmosphere with the flue gases, while nuclear-fueled units release all but 0 to 50% of their waste that heat through cooling condensers (Pigford et al., 1974). Together, these differences cause nuclear-fueled units to consume 39 to 50% more cooling waters than coal-fired units on a per MWe basis (Harte and El-Gassein, 1978, p. 628). Comparable figures from Brill et al. (1980) indicate consumptive loss to be nearly 70% greater for nuclear units.

Table 12 compares water withdrawals with consumptive loss for standard coal-fired and nuclear-fueled scenario units under different cooling technologies. Withdrawal is the amount of water that must be taken from the source water body for cooling purposes. Consumption refers to the amount of water lost from the local hydrologic system as a result of cooling system operation. Consumption is always less than withdrawal but the difference between the two varies as a function of the type of cooling, as well as other factors. Consumption can be calculated as the difference between withdrawals from and returns to local water bodies. In the case of wet cooling towers, consumption is due to evaporative cooling loss to the atmosphere because this water cannot be expected to be returned to the local hydrologic system. Once-through cooling consumed significantly less water but withdraws considerably more water than wet towers or ponds to accomplish the same cooling.

Water resources are also in demand for purposes other than power generation. The available surface water supplies are required to serve other industries and municipal needs while furnishing sufficient flow to maintain navigation and a healthy aquatic environment. Consequently, power generation can only be allocated a certain portion of the available water. Competition for use of the local water resources is generally most acute during periods of low flow. Thus, a valid measure of water availability must reflect low flow conditions. The usual measure is the low flow that persists for seven days and can be expected to occur once every ten years -- i.e., 7-day/10-year ($_7Q_{10}$) low flow. Selection of the 7-day duration low flow is usually based on evidence that aquatic organisms often can tolerate several days of stress but not weeks or months (Hynes, 1970).

Consistently reliable quantitative data on water availability for the ORBES region are available for streamflow only. Comparable data are not available for groundwater or potential reservoir yields. Consequently, potential methods of augmenting streamflow, (such as constructing reservoirs and pumping groundwater or stream water) and using dry cooling towers to reducing cooling water requirements are accounted for in the ORBES siting model by giving counties with low $_7Q_{10}$ low flow values relatively low suitability scores for water availability rather than excluding them from consideration as candidate sites. This simulates electric utility company behavior. Utilities prefer to locate capacity additions immediately adjacent to a large supply of water with sufficient $_7Q_{10}$ low flow. If that is inconvenient, a site may be selected on a smaller body of water where some type of augmentation may be necessary in order to generate at peak capacity. If utilities are forced to move further

Table 12. COOLING WATER REQUIREMENTS FOR SCENARIO UNIT ADDITIONS
(in CFS/Unit)

Cooling Technology	Withdrawal	Consumption
Coal-fired Units (650 MWe/unit)		
Wet Towers	16.6	10.4
Once-through Cooling	910.0	6.5
Ponds	16.6	10.4
Nuclear-fueled Units (1000 MWe/unit)		
Wet Towers	43.0	27.0
Once-through Cooling	2000.0	15.0
Ponds	43.0	27.0

SOURCE: Brill et al., 1980.

inland, it may be necessary to utilize groundwater, pump stream water over long distances (25-30 miles) or install dry cooling towers. Each successive option would cost the utility more in terms of capital and operating outlays, and risk problems with impacts on land use and ecological systems. The siting model simulates these "costs" by assigning lower suitability scores to areas that must depend upon streamflow augmentation.

Site Suitability for Water Availability

Suitability scores for the water availability component of the siting model are assigned on the basis of $_7Q_{10}$ low flow values for streamflow (Table 13). Each county in the ORBES region is assigned a single $_7Q_{10}$ low flow value by summing values based on Brill et al (1980) for each gauged stream within or adjacent to the county. For many counties, $_7Q_{10}$ values are estimated because no gauges are located along stream reaches within or adjacent to the counties. In these cases, a linear extrapolation between appropriate gauging stations is used except when topographic maps indicate contributions from tributaries justify modification of the linear extrapolation estimate.

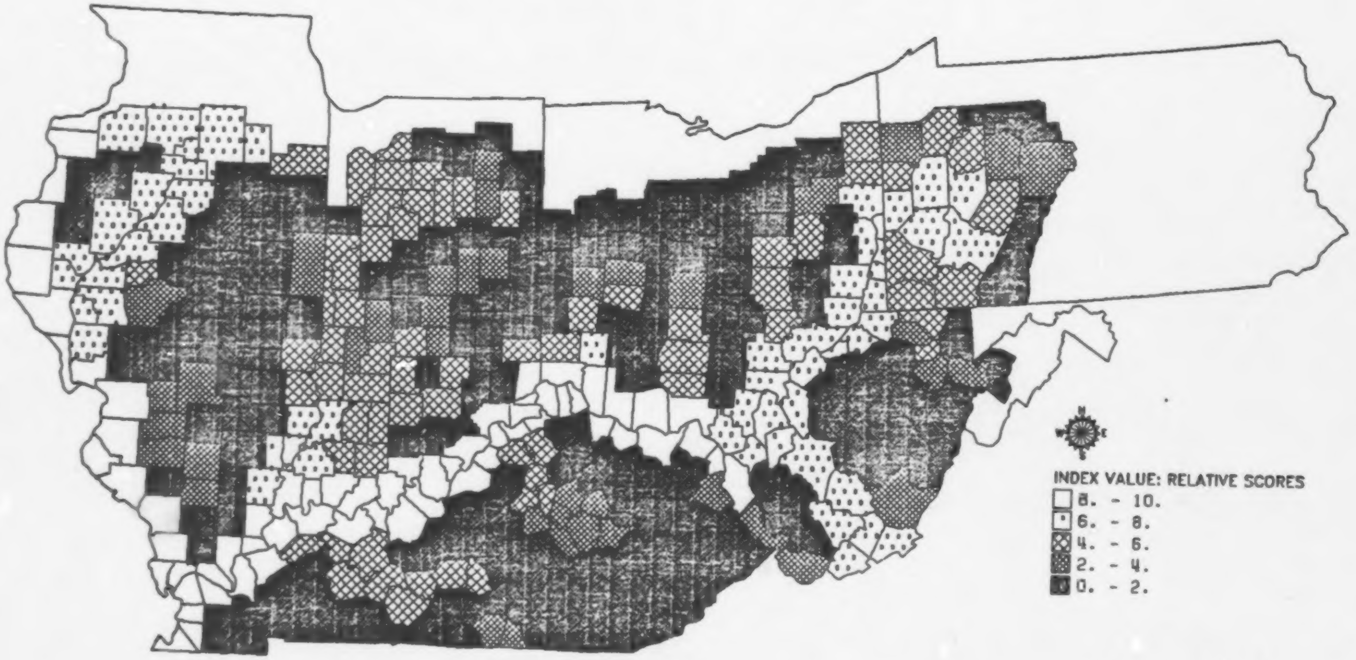
Site suitability scores vary directly with the amount of cooling water available. Counties with less than or equal 10 cfs for $_7Q_{10}$ low flow are not excluded as a generating site although this is not enough water to supply the consumptive requirements of a 650 MWe coal-fired unit operating at maximum output. Augmentation is taken into consideration at the low end of the suitability range. The cooling water consumption requirements for an electrical generating unit cannot claim all available stream flow. As a guide, no more than 10% of the $_7Q_{10}$ low flow can be used. In the ORBES siting model, two or more scenario unit additions can be sited in a county only if the water availability score for the county is greater than four for coal-fired units, or greater than five for nuclear-fueled units. Streamflow augmentation or alternative cooling technologies could support multiple units in counties with lower scores but these alternatives are judged to be prohibitively expensive.

The pattern of relative county suitability scores for the water availability component in the ORBES region varies by location on the stream network (Figure 19). Counties in the highest suitability range (scores = 8-10) are found along the Ohio River below Huntington, West Virginia and along the Mississippi River on the western borders of Illinois and Kentucky. Counties in the next suitability range (scores = 6-8) are located along the Allegheny and Monongahela Rivers in Pennsylvania; along sides of the Ohio River from Pittsburgh, Pennsylvania to Huntington, West Virginia; along the Kanawha and New Rivers throughout their lengths in West Virginia; along the lower Wabash River in Indiana and Illinois; and on the Illinois and Rock rivers in Illinois. Counties in the low end of the range suitable for more than one generating unit (scores = 4-6) are found further upstream on the Allegheny River in Pennsylvania and the Monongahela River in Pennsylvania and West Virginia; on the Mahoning, the Muskingum, the Scioto and the Miami rivers in Ohio; along the Green River and the Kentucky River in Kentucky; on the Wabash, both forks of the White, and the Kankakee Rivers in Indiana; and along the Wabash, Kankakee, and Sangamon Rivers in Illinois. Counties with lower suitability scores occupy the remaining upland areas of the ORBES region.

Table 13. WATER AVAILABILITY COMPONENT SCORES

Σ $_7Q_{10}$ Flow for County (cfs)	Score
$\geq$ 20,000.1	10
10,000.1 - 20,000	9
5,000.1 - 10,000	8
1,000.1 - 5,000	7
200.1 - 1,000	6
100.1 - 200	5
50.1 - 100	4
20.1 - 50	3
10.1 - 20	2
$\leq$ 10	1

Figure 19. **WATER AVAILABILITY COMPONENT**



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Land Use And Ecological Systems

The land use requirements for electrical generating facilities can be substantial.[6] At a coal-fired facility, land is required for the main boiler unit, cooling towers or ponds, coal storage, ash disposal and roads associated with the facility. For six (6) coal-fired facilities under construction in the ORBES region, utility land ownership averaged 1,050 acres per 650 MWe capacity. Using this figure, present (1976) land use at energy conversion facility sites in the ORBES region is estimated at 140,673 acres. If land requirements for high voltage transmission line rights-of-way (estimated at 600,000 acres in 1976) are also considered, land use conversion is even higher. Nuclear-fueled generating units and associated facilities, including space for fuel storage and the exclusionary area surrounding the reactor site, also use a significant land area. Land is converted to energy-related use for at least the life of the plant. Consequently, change in land use and ecological systems are important issues in power plant siting.

A variety of regulatory legislation and agency policies contain provisions that are relevant to the impacts of generating unit additions on land use and ecological systems. These include the National Historic Preservation Act (PL 89-665), The Endangered Species Act (PL 93-205), The Federal Land Policy and Management Act (PL 94-579) and the National Forest Management Act (PL 94-588). Their effect has been to increase the range of impacts that are considered in environmental reviews, and the relative importance of each to actions such as power plant siting. The definition of land use and ecological systems that is sensitive to environmental decisions depends, to a large extent, on the scarcity of resources. As a resource becomes more scarce, its value as an element of land quality can also increase.

Four indices are selected to represent siting issues relevant to land use and ecological systems in the ORBES region (Table 14). These are: natural, scenic and recreational areas; sensitive and protected environments; agricultural and ecological productivity; and the ownership and management of forest lands. Each represents a resource that is important to subregions in the ORBES area. Agricultural and ecological productivity, for example, is of central importance in prime agricultural lands, which are concentrated north of the Ohio River whereas conflict involving forest lands are more likely to occur in the southern and eastern portions of the region. Each variable also has reliable county-level data for all six ORBES states, as uniform data are essential in making comparisons among the indices. Absolute values for each variable are normalized on a scale of 0 to 10, with an index of "uniqueness" used for sensitive and protected environments (Randolph and Jones, 1980). The weights assigned to each parameter can reflect evaluations of the relative importance of the resources, as well as scenario policy issues. They are combined to form a suitability index for the land use and ecological systems component.

X_1 Natural, Scenic and Recreational Areas

The extent of public lands is used as the measure of natural, scenic and recreational areas. Public lands are all state and federally-owned lands that are managed for special

Table 14. DEFINITION OF THE LAND USE AND ECOLOGICAL SYSTEMS COMPONENT

X_1 Natural, Scenic and Recreational Areas % County in Public Lands	X_2 Sensitive and Protected Environments	X_3 Agricultural and Ecological Productivity % County in Class I & II Soils	X_4 Forest Lands Ownership and Management % County in Non-Federal Forest
X_1 = 0 - 5 = 1	$X_2 = \sum_{i=1}^{3} U_iN_{ij}$ where U_i is a uniqueness coefficient 1 = normal 2 = medium 3 = high N_i is number of areas in each category.	X_3 = 0 - 10 = 1	X_4 = 0 - 10 = 1
5.1 - 10 = 2		11 - 20 = 2	11 - 20 = 2
10.1 - 15 = 3		21 - 30 = 3	21 - 30 = 3
15.1 - 20 = 4		31 - 40 = 4	31 - 40 = 4
20.1 - 25 = 5		41 - 50 = 5	41 - 50 = 5
25.1 - 30 = 6		51 - 60 = 6	51 - 60 = 6
30.1 - 35 = 7		61 - 70 = 7	61 - 70 = 7
35.1 - 40 = 8		71 - 80 = 8	71 - 80 = 8
40.1 - 45 = 9		81 - 90 = 9	81 - 90 = 9
45.1 - 50 = 10		91 - 100 = 10	91 - 100 = 10

Component Index $(C_{j3}) = W_1X_{1j} + W_2X_{2j} + W_3X_{3j} + W_4X_{4j} = \sum_{i=i}^{4} W_iX_{ij}$

where W = weighting factor for the ith criterion
X = numerical ranking for the ith criterion in the jth county

uses. They include all state and federal parks, forests, wildlife areas, public hunting and fishing areas, historical landmarks, and government installations such as Fort Knox, Kentucky and The Crane Naval Munitions Depot in Indiana.

The majority of the public lands are concentrated in the southern part of the ORBES region (Figure 20). Parks, forests and wildlife areas account for the majority of counties that have relatively high scores. Counties that have $\geq$ 50% of their area in public lands are assigned a score of 0.0, which excludes them from consideration.

X_2 Sensitive and Protected Environments

An index of "uniqueness" for natural areas is used as the measure of sensitive and protected environments. These include state nature preserves and other natural areas that are generally recognized by state and academic authorities as having important ecological significance. Counties that have the highest uniqueness scores are in Illinois, Ohio and Pennsylvania (Figure 21).[7] They may be less suitable as sites for new electrical generating units because of the need to consider the impacts that might result from facility location or design. However, because sensitive and protected environments generally do not occupy large areas, they are not considered to be exclusionary criteria.

X_3 Agricultural and Ecological Productivity

The extent of Class I and Class II soils is the measure of agricultural and ecological productivity. The distribution of Class I and Class II soils defines the potentially most productive parts of the agricultural lands in the ORBES region. These prime agricultural lands account for 39% of the total area in the region and 72% of the agricultural lands. Corn is the most important crop, with much smaller acreages in soybeans and winter wheat. These and other conventional grains are important sources of food and feed. The U.S. Department of Agriculture (USDA), USEPA and other federal and state agencies have recently adopted policies designed for the preservation of agricultural land. The conversion of farm land for energy related activities, such as coal mining and power plant siting, is a special concern in the prime agricultural lands of the ORBES region.[8]

The largest extent of prime agricultural land is located in a wedge from central Illinois through central Indiana and west central Ohio (Figure 22). This highly productive, relatively level farmland is devoted primarily to corn, soybeans and other cereal grains that are used for feed and food. Counties around the periphery of this wedge, and in the southwestern part of Indiana and western Kentucky, have smaller portions of their land

Figure 20. **NATURAL, SCENIC, AND RECREATIONAL AREAS**

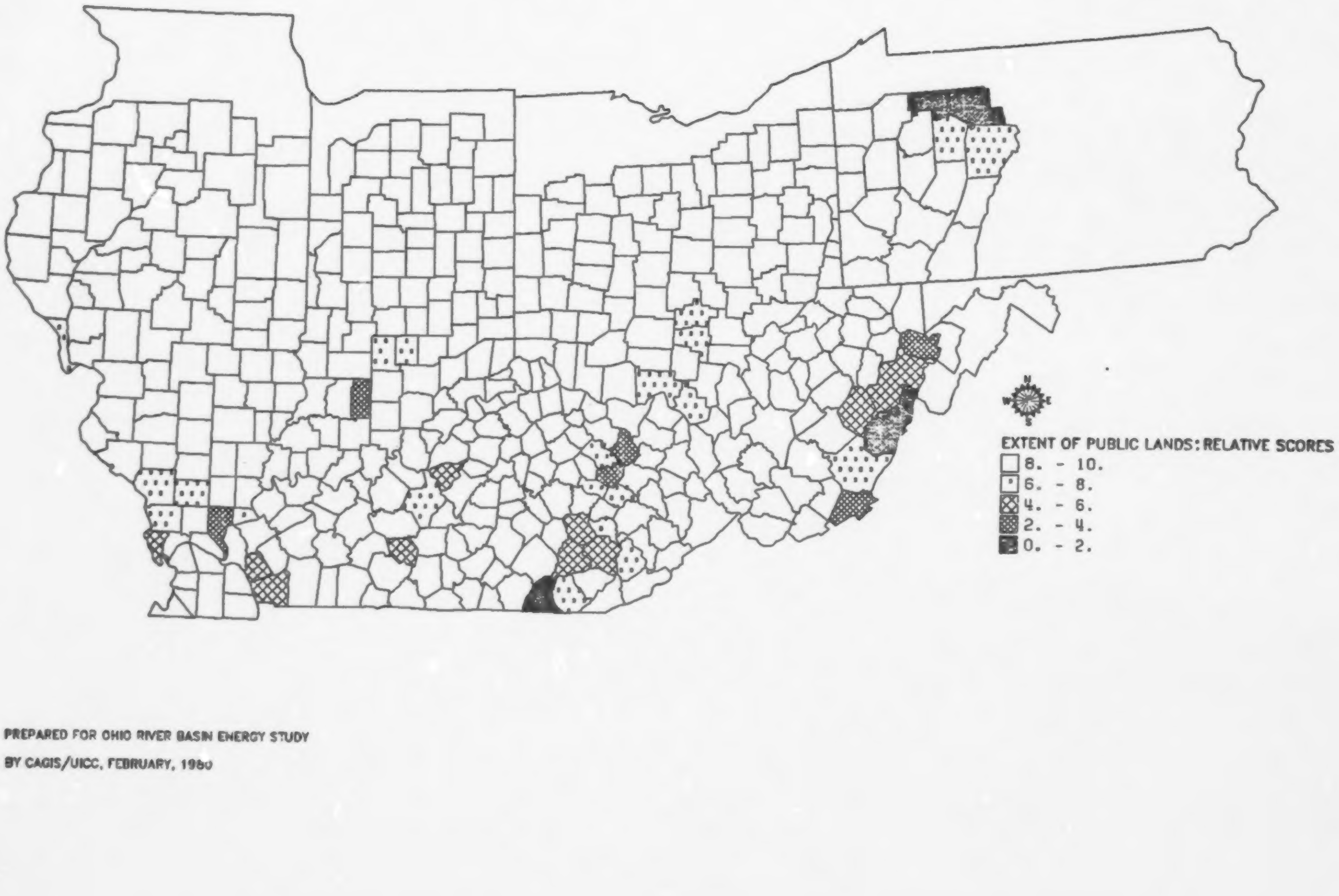

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Figure 21. **SENSITIVE AND PROTECTED ENVIRONMENTS**

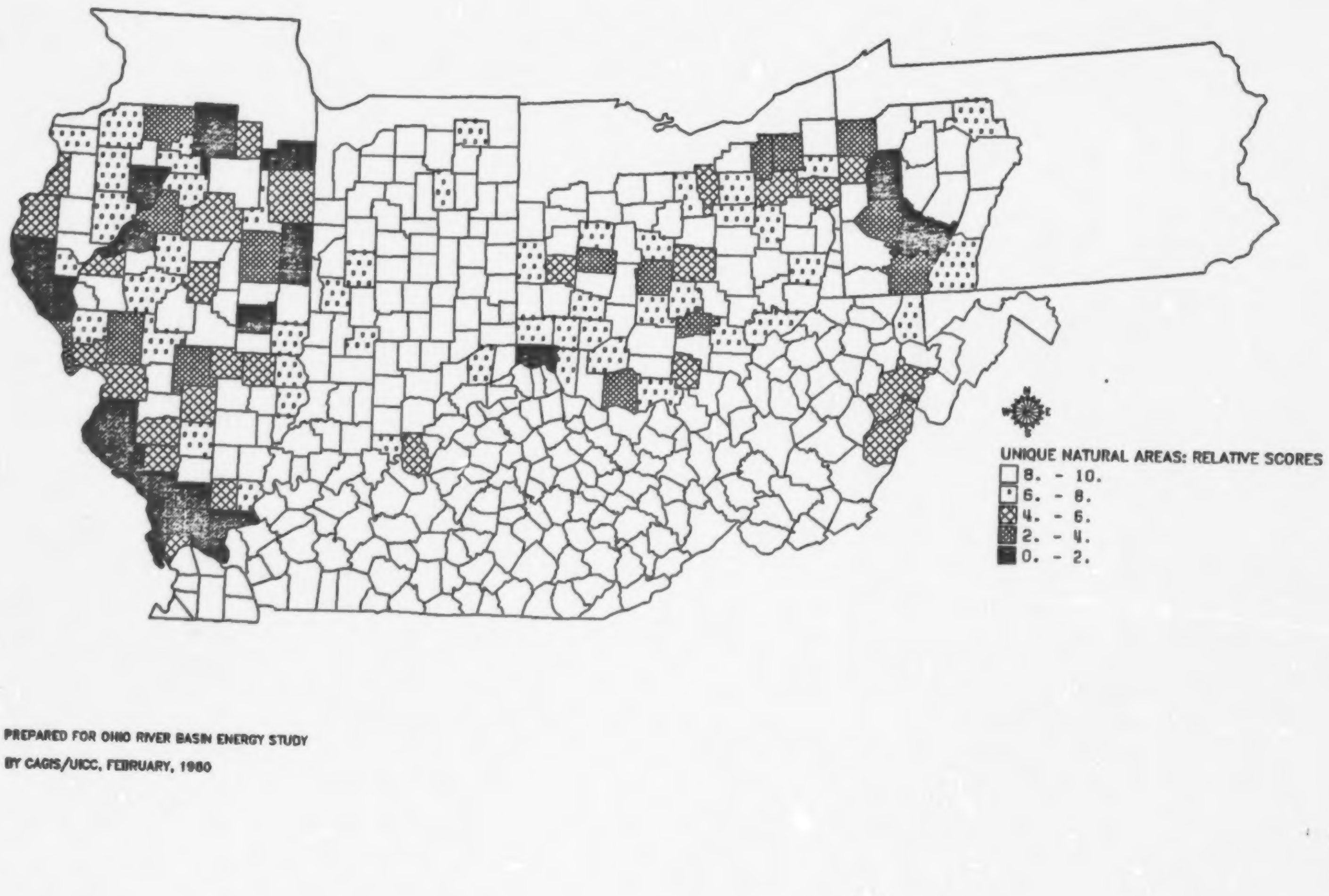

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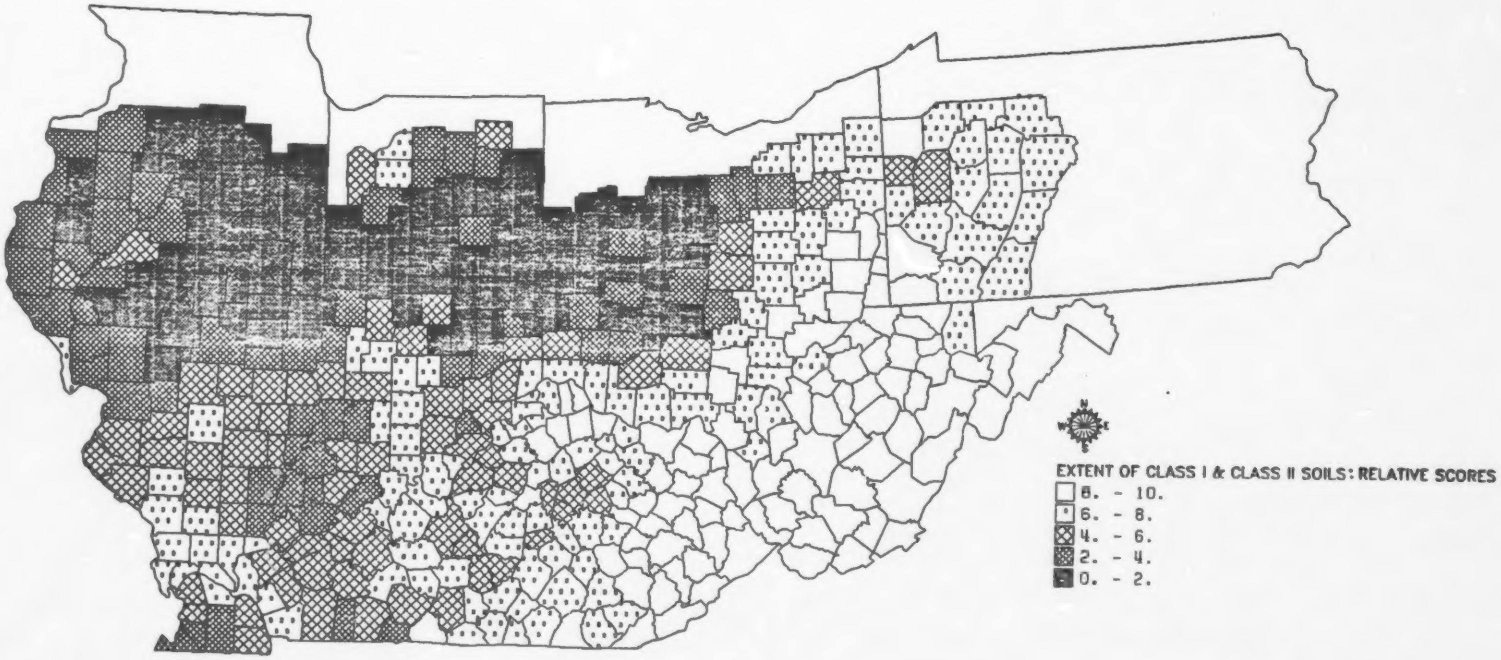
Figure 22. **AGRICULTURAL AND ECOLOGICAL PRODUCTIVITY**



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area in Class I and II soils. Except for specialized agricultural areas, such as the Bluegrass Basin in north central Kentucky, the remainder of the southern and eastern part of the region has relatively little high quality land. Counties that have relatively high suitability scores are considered to be less suitable as sites for new generating units than those with low suitability scores. However, agricultural and ecological productivity is not a sufficient condition to exclude a county from consideration.

X_4 Ownership and Management of Forest Lands

The extent of non-federal forests is the measure of the ownership and management of forest lands. Federal forests are not included, as they are represented in the public lands category. The distribution of non-federal forests is the mirror image of the map of Class I and Class II soils (Figure 23). The majority of the forests are in the Appalachian areas of eastern Kentucky and West Virginia, southeastern Ohio and western Pennsylvania. Kentucky has the largest number of acres whereas West Virginia has the largest proportion of its land area in forests. Most of the forests are in small, privately-owned tracts. Forest products, primarily hardwoods, are used for manufactured wood products.

In combination, the impact of ecological systems and land use criteria on reducing the suitability of counties as sites for coal-fired and nuclear-fueled scenario unit additions is greatest in Illinois, Indiana and Ohio, and in the extreme eastern part of the region (Figure 24). Illinois has the largest number of counties with relatively low (≤ 6) suitability scores. Compared with other states, the geography of ecological and land use resources in Illinois is complex. Prime agricultural lands is the dominant factor in reducing the suitability of counties in Indiana and western Ohio, whereas natural areas and forest lands are most important in Pennsylvania and West Virginia. Ecological systems and land use factors add constraints to site selection in these counties, but they alone are not sufficient under current practice to exclude a county from consideration.

Seismic Suitability

Seismic suitability is an important consideration in siting nuclear-fueled electricity generating units. The safe operation and shutdown of nuclear reactors under the stress of earthquake vibrations is at issue. Seismic criteria are included in evaluating the physical characteristics of proposed sites (Title 10, CFR, Part 100). The applicant for a construction permit is required to perform certain specified engineering and geologic investigations to determine: 1) the maximum vibratory ground motion produced by the strongest earthquake that could potentially affect the site; 2) whether and to what extent the proposed nuclear power plant should be designed for surface faulting; and 3) the potential for the site to be exposed to seismically induced water waves or floods. Even if seismic site characteristics are unfavorable,

Figure 23. **OWNERSHIP AND MANAGEMENT OF FEDERAL FORESTS**

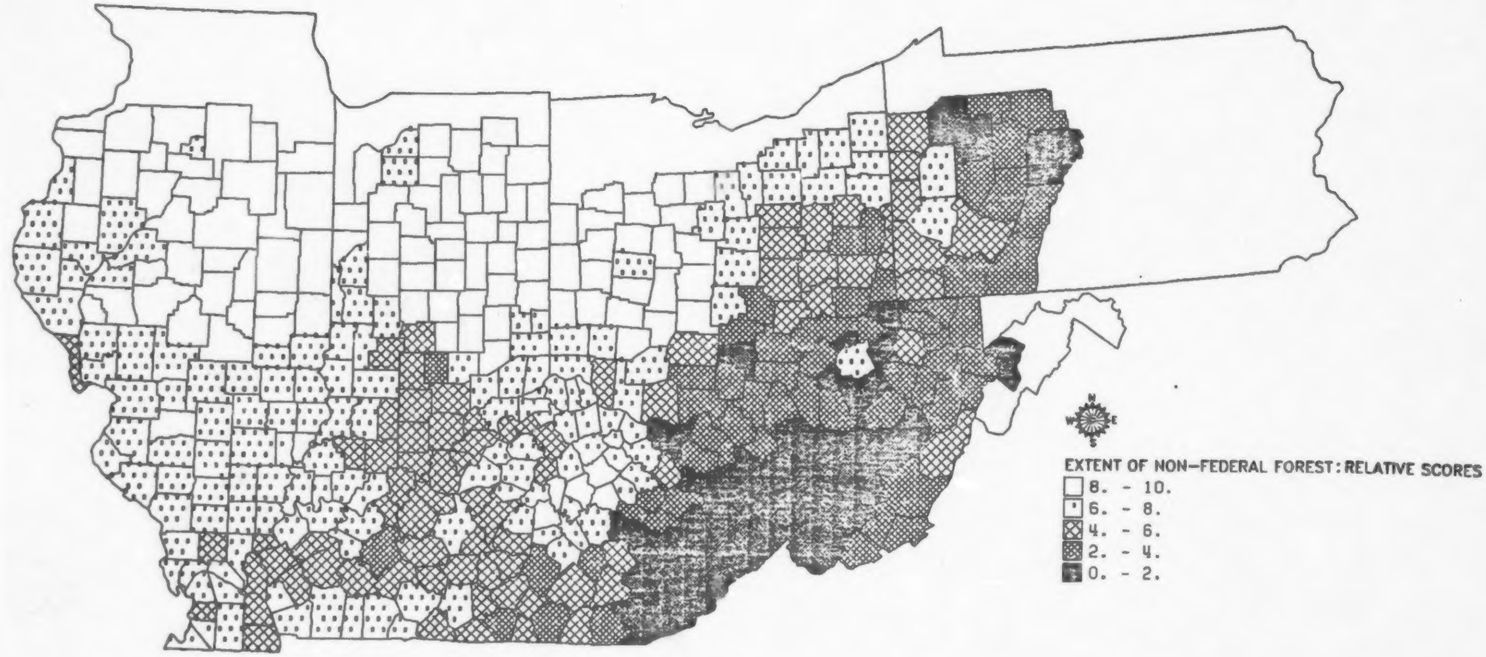

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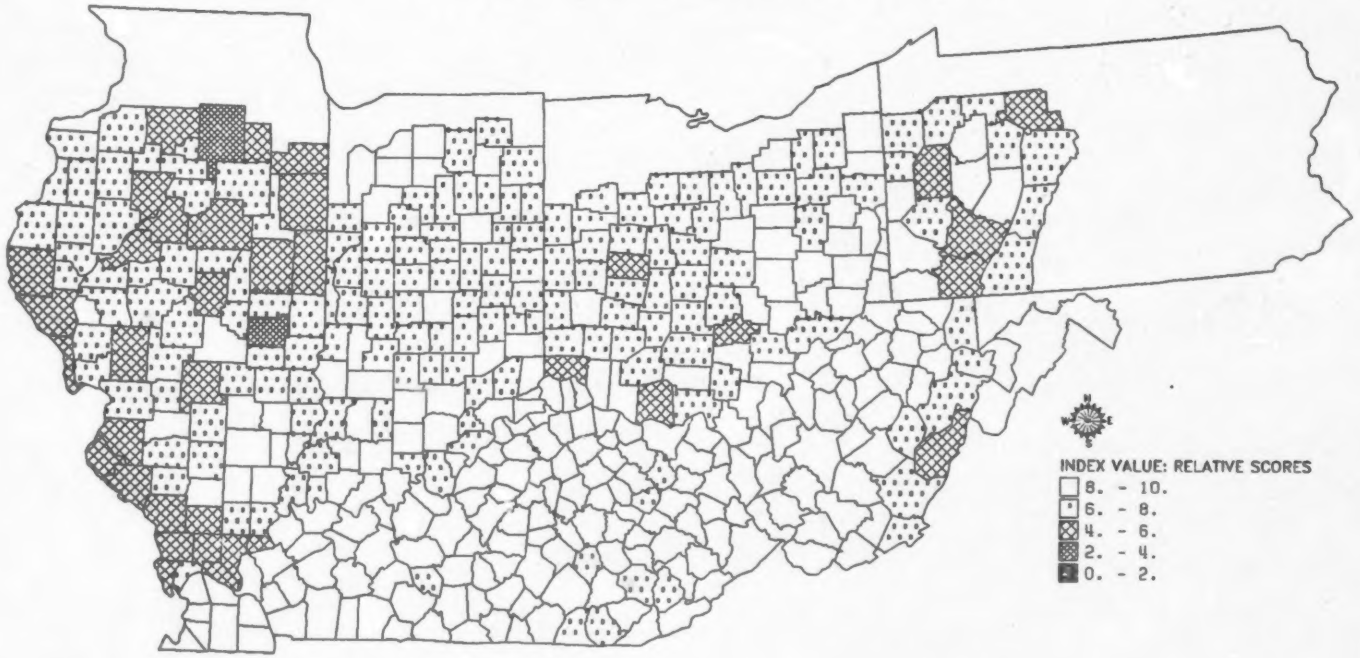
Figure 24. **ECOLOGICAL SYSTEMS AND LAND USE COMPONENT**

STRICT ENVIRONMENTAL CONTROLS



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the proposed site may be approved if facility design includes appropriate and adequate compensating engineering safeguards. The guiding principle in the NRC's determination as to seismic suitability of a proposed nuclear generating station is whether or not the proposed design is adequate to provide for the safe shutdown of the reactor under the worst credible earthquake or fault conditions that could affect the site.

Electric utility companies consider seismic criteria as economic factors. The consulting geogolists that are required for site investigation in active or potentially active seismic zones, and capital outlays and engineering for improved seismic design, can be very expensive. Last minute licensing delays resulting from inadequate preliminary geologic -- geotechnical siting studies have, in several cases, contributed to abandoning certain proposed sites (McClure, Jr. and Hatheway, 1979, p. 6). Consequently, utilities tend to avoid siting nuclear reactor zones that are seismically very active and to review carefully the costs and benefits of sites in areas that have even occasional significant seismic activity.

Earthquakes in the central United States have several characteristics that distinguish them from their western counterparts. They occur infrequently; none has produced surface breakage in historic times; their seismic wave energy shows much smaller anelastic attenuation; and, as a result of the first two reasons, less is known about them (Nuttli, 1979, p. 92). Three broad areas of the ORBES region are accompanied by some degree of seismic risk. These are:

1. The southwestern part of the region, including southern Illinois, western Kentucky and southwestern Indiana.

2. A small area in the northcentral portion of the region, including ten counties in west-central Ohio.

3. The eastern part of the region, including portions of western Pennsylvania, West Virginia and a few counties in southeastern Kentucky.

The most significant of these is the area in the southwestern part of the region. It includes parts of the New Madrid and the St. Francois seismic zones, and the entire Wabash Valley seismic zone.

The New Madrid seismic zone has been by far the most active seismic region in the central United States during the last 200 years (Nuttli, 1979, p. 68). The three principal shocks that occurred in this portion of southeast Missouri in 1811 and 1812 had body-wave magnitudes greater than 7.0. Minor damage was experienced as far north as Lake Michigan and as far east as West Virginia.[9] Two other areas have histories of earthquake activity. One is centered on Shelby County, Ohio and the other is the Appalachian Plateau in the eastern part of the region. Although neither of these has historically experienced earthquakes of sufficient magnitude to preclude nuclear generating stations, the need for conservative, and thus more expensive, seismic design could influence the decision to site in these areas.

Seismic criteria are included in the ORBES siting model to simulate the decision-making process of electric utility companies in evaluating sites for nuclear reactors. Certain areas are excluded from consideration as candidate sites for nuclear units and other areas were given relatively unfavorable suitability scores depending on the degree of difficulty one might encounter in searching for a site that would be acceptable to the NRC and could be built on at reasonable cost.

Suitability is based on a county's location with respect to the three seismic zones that the NRC used in coarse screening to identify potential nuclear energy center siting regions (U.S. Nuclear Regulatory Commission, 1976, pp. 2-6, 2-7). These zones are:

- Zone I: includes areas of low seismicity with no known capable faults. It is expected that seismically suitable sites can be found with little difficulty.
- Zone II: includes areas with moderate seismicity and complex geological structures, having numerous, old, incapable faults; and areas close to zones of high seismic risk, that may lead to controversial risk assessment. Detailed site-specific studies would be necessary to determine geologic and seismic site suitability.
- Zone III: is characterized by high seismicity, accompanied in most cases by intense, recent faulting. In general, the cost and time required for investigation of site suitability makes it impractical to consider these areas for nuclear power plants.

The relative seismic suitability zones are depicted by the NRC on a series of regional maps that are used to assign seismic suitability scores to counties for the ORBES siting model (Table 15). For example, a county that is located entirely in Zone III is assigned a score of 0.0, which excludes it from consideration for a nuclear reactor unit. Other counties are assigned standard scores depending on their location relative to the three seismic zones.

Counties in southern Illinois, southwestern Indiana and extreme western Kentucky that are entirely in seismic Zone II or are in Zone II and III, are either excluded from consideration as candidate sites or have very low suitability scores (Figure 25). They are bordered by counties that are more suitable with respect to seismicity, although potential sites for nuclear reactors in these areas usually are subject to careful evaluation. Another large area of moderate seismic suitability is located in the Appalachian Plateau of West Virginia and western Pennsylvania. The areas of low seismic suitability are geographically coincident with the location of extensive coal reserves. Although no nuclear reactors are located in these areas, a large number of coal-fired generating units are in service and others are planned.

Population Distribution

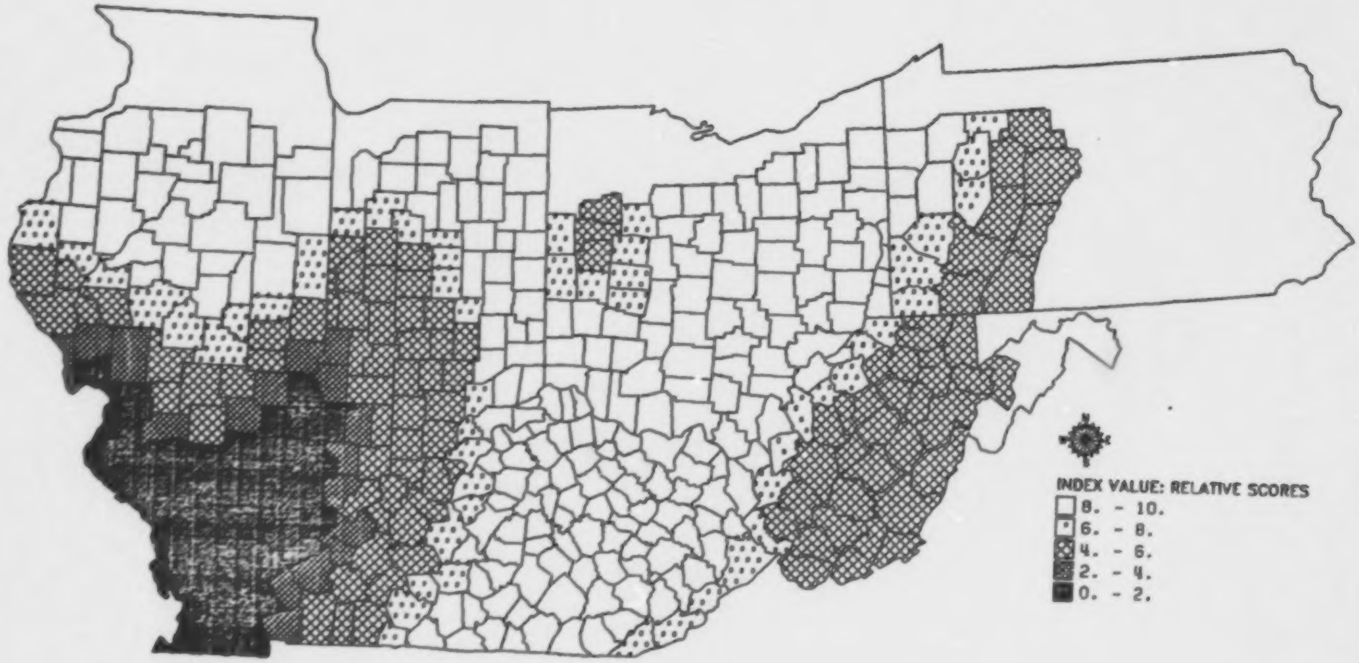
Federal regulations encourage siting nuclear reactors away from large concentrations of population. Title 10 CFR, Part 100 specifically includes pop-

Table 15. DEFINITION OF SEISMIC SUITABILITY SCORES FROM RELATIVE SEISMIC SUITABILITY ZONES

County Location	Relative Seismic Suitability Zone[a]	Relative Score
Entirely in Zone	I	10.0
In both Zones	I-II	7.5
Entirely in Zone	II	5.0
In both Zones	II-III	2.5
Entirely in Zone	III	0.0

[a] Source: U.S. Nuclear Regulatory Commission, 1976, pp. 2-1 and 2-6.

Figure 25. **SEISMIC SUITABILITY COMPONENT INDEX**



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ulation distribution characteristics among the factors to be considered in determining site acceptability. Public health and safety is the issue. Although the NRC does not define levels of acceptability for population characteristics, locating reactors away from densely-populated areas is considered to be the most important siting constraint in states such as Illinois (Laney and Gustafson, 1979). The problem is to minimize transportation and land acquisition costs while maximizing system safety and reliability. During the 1970's, the trend in nuclear reactor siting has been to locations away from densely-populated areas with access to the utility grid and adequate water supplies.

The NRC has developed a technique for describing population characteristics that can be used in evaluating alternative sites for nuclear reactors. The site population factor (SPF) is an index that weights the cumulative population with a function that decreases with increasing distance from the proposed reactor site (Kohler, Kenneke and Grimes, 1975). This is consistent with the idea that risk to an individual decreases as distance from the source of radioactivity increases. The distance factor is derived from an analysis of meteorological dispersion data; and the population distribution is normalized to an area with a uniform density of 1000 persons per square mile. With a bounding radius of 30 miles, a SPF = 0.3 is equivalent to 300 persons per square mile distributed uniformly out to a distance of 30 miles from the proposed reactor site.

SPF contours have been drawn for the contiguous United States using 1970 residential population data (Kohler, Kenneke and Grimes, 1975). The maps assumed locations at the intersections of each 0.1 degree latitude and longitude lines for densely populated areas, and at the intersection of each 0.25 degree lines for low density areas. At this scale, the SPF maps clearly outline the major cities and their urbanized areas (Louisville, Kentucky; Indianapolis, Indiana; Cincinnati-Dayton and Columbus, Ohio; and Pittsburgh, Pennsylvania). Each occupies an area with SPF contours of 0.5 and higher. Most smaller metropolitan areas are also shown, although they have SPF contours of between 0.4 and 0.2.

The population distribution component of the siting model is based upon 1970 county population densities. Counties are rated on a scale of 1 to 10, according to densities that are analagous to SPF's at a distance of 30 miles (Table 16 and Figure 26). Counties with low scores have high population densities with a score of 5 equivalent to a SPF = 0.5, or 500 persons per square mile. Counties with the lowest suitability scores are those which have the central cities of large metropolitan areas. Most other counties that have scores $\leq$ 8 contain the urbanized areas of large cities or are smaller metropolitan areas. Counties with a relative score $\geq$ 5 (i.e., a SPF = $\geq$ 0.5) are excluded from consideration as candidates for nuclear-fueled scenario unit additions.

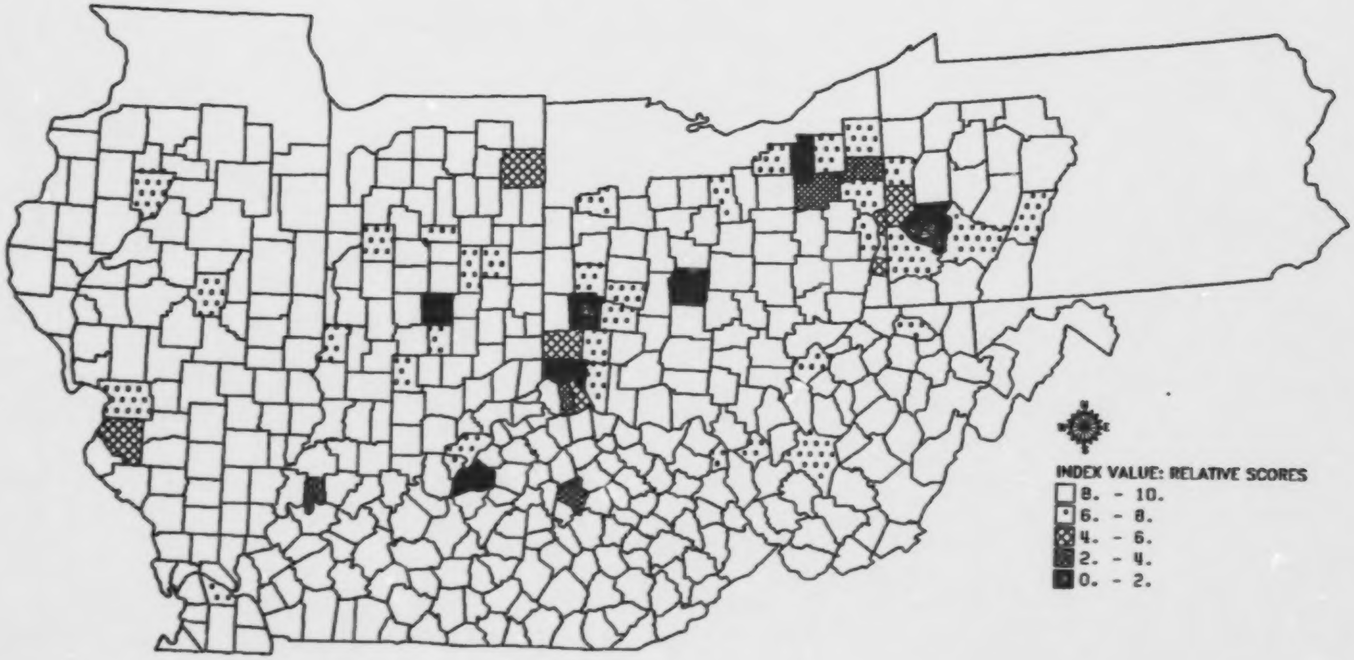
DEFINITION OF SITING WEIGHTS

The definition of siting weights for the ORBES region is based upon information collected using a modification of the Nominal Group Porcess Technique (NGT). Given the specification of siting components, members of the ORBES Core Team and Advisory Committee were asked to evaluate the relative

Table 16. SUITABILITY SCORES FOR POPULATION DISTRIBUTION COMPONENT

Population Density, 1970	County Score
0 - 99.999	10
100.0 - 199.999	9
200.0 - 299.999	8
300.0 - 399.999	7
400.0 - 499.999	6
500.0 - 599.999	5
600.0 - 699.999	4
700.0 - 799.999	3
800.0 - 899.999	2
≥ 900.0	1

Figure 26. **POPULATION DISTRIBUTION COMPONENT**



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importance of each criterion to siting a standard 650 MWe coal-fired or 1000 MWe nuclear-fueled electrical generating unit within the region. The functional relationships of each component and variable to regional siting issues had been discussed previously in presentations to the Core Team and Advisory Committee.

Each person indicated his or her evaluation of the relative importance of the criteria on a specially designed instrument (Figure 27). The relative weight for each component was shown by a line drawn to the appropriate point on a continuous graphic scale from 0 (unimportant) to 10 (most important). According to Voelker (1977, pp. 2-3), such a scale is appropriate for a group which is "technically qualified to make refined distinctions" among siting criteria. The scale is also appropriate for the level of detail and accuracy desired from the siting model.

The first round voting involved relatively little prior discussion about the substantive issues of power plant siting. The objective was to obtain an initial set of data. After the results were tabulated, the group reconvened for a second round of voting. Each person received a tabulation of the mean and standard deviation for each criterion as well as her or his original vote. The group discussed the importance of the siting criteria to the ORBES region and the distribution of individual evaluations for approximately one hour prior to the second vote. The objective of the second iteration was to improve the accuracy of the group output, and to reduce the dispersion among individual votes.

The methodology was an optimal use of the NGT technique that ORNL had previously applied to develop the siting model for the National Coal Utilization Assessment (Davis et al, 1979).[10]

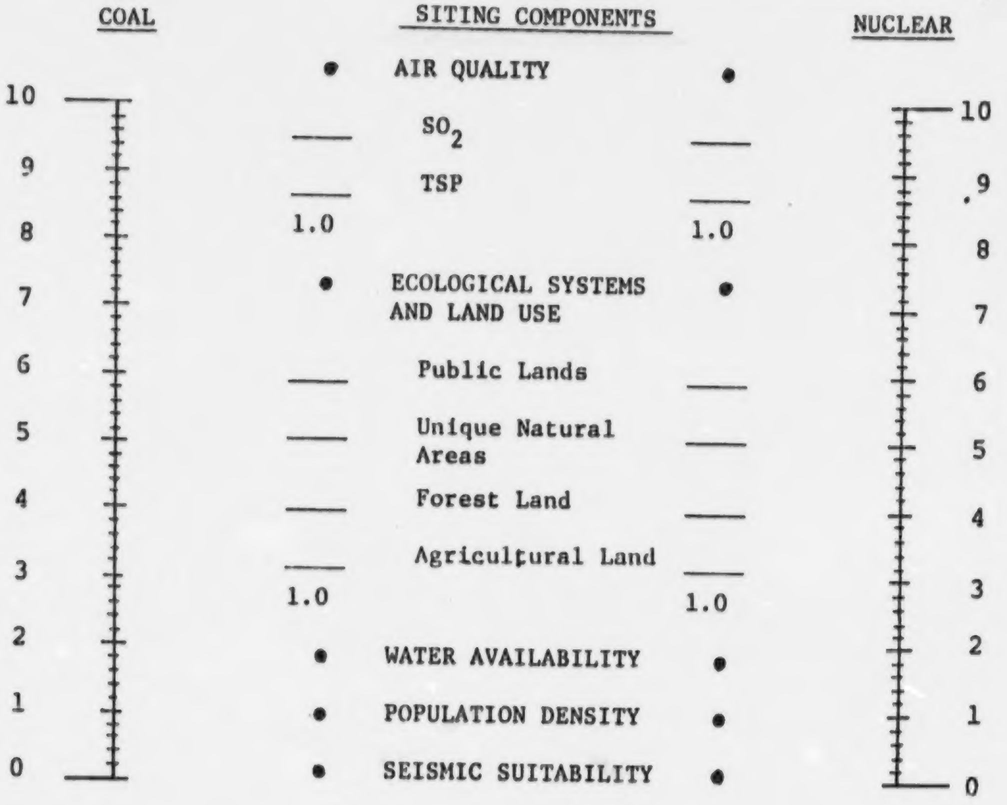
1. The siting components and variables had been selected to represent issues that were especially relevant to power plant siting in the ORBES region, and central to the assessment's scenario policies. The issues had been thoroughly discussed and presented to the Core Team on several occasions. Thus, the first three steps of the NGT process were unnecessary (Voelker, 1977).

2. The siting criteria were evaluated with respect to locating scenario unit additions in the ORBES region only. An evaluation of criteria "in general" (i.e., at national scale) is inappropriate for a regional technology assessment.

3. The relative importance of the criteria were evaluated simultaneously for coal-fired and nuclear-fueled units.

No attempt was made to evaluate "site specific" criteria, as the objective of the ORBES siting methodology is to distribute scenario unit additions at regional scale.

Figure 27. DEFINITION OF WEIGHTS FOR SITING COMPONENTS



SITING COMPONENTS

● AIR QUALITY ●

____ SO_2 ____

____ TSP ____

1.0 1.0

● ECOLOGICAL SYSTEMS AND LAND USE ●

____ Public Lands ____

____ Unique Natural Areas ____

____ Forest Land ____

____ Agricultural Land ____

1.0 1.0

● WATER AVAILABILITY ●

● POPULATION DENSITY ●

● SEISMIC SUITABILITY ●

The rank order of the siting components, and most variables, for each fuel type were the same in Round 2 as in Round 1 (Table 17 and 18). The means of some criteria changed significantly. However, the standard deviation decreased in all cases except one. The objective of increasing group agreement in the second round of voting was achieved.

Ambient air quality was judged to be the most important consideration for siting coal-fired plants. Population density and seismic suitability were most important for nuclear-fueled units. These results were expected. However, the fact that the ecological systems and land use component ranked higher than water availability for both fuel types was not consistent with the results of similar siting studies. Ecological systems and land use variables have a more prominent role in the ORBES siting model than in those that are national in scale. The importance assigned to this component underscores the sensitivity of the model to the regional characteristics of the study area.

Although the ecological systems and land use component was considered to be slightly more important for siting coal-fired units, the weights were essentially the same for each round of voting and across fuel types. Even the change in importance of the unique natural areas and agricultural lands variables in the Round 2 voting was the same for coal-fired and nuclear-fueled units. Water availability was considered to be almost as important as ecological systems and land use in siting nulcear units. But for coal-fired units, water availability was evaluated significantly lower on the scale.

Water availability and engineering considerations were the most important siting variables in ORNL's evaluation. Ecological considerations were next in importance, with land use compatability identified as an issue that electric utilities and others perceived as a central issue in site selection. However, water resources are considered to be relatively plentiful in the ORBES region. Supplying the water requirements of standard plants is considered to be an economic matter, and thus less restrictive than ecological, land use and air quality criteria for siting new electricity generating facilities.

The application of NGT to the ORBES siting issues resulted in a consistent set of weights that can be used with confidence in calculating site suitability indices for siting standard coal-fired and nuclear-fueled electricity generating facilities in the study region. The weights are a type of baseline data that are sensitive to expert evaluations of the relative abundance of regional resources, such as water, and their importance in siting generating capacity additions under current economic, regulatory and technological conditions. Policies that may affect power plant siting by altering any of these assumed relationships can be simulated by systematic changes in the weights, as well as the set of candidate counties to which they apply.

Definition Of Site Suitability for Basic Scenarios

Three formulas define the suitability of counties in the ORBES region as sites for coal-fired or nuclear-fueled generating units additions in the basic scenarios. These are:

Table 17. WEIGHTS FOR SITING COMPONENTS AND VARIABLES FOR COAL-FIRED ELECTRICITY GENERATING FACILITIES IN THE OHIO RIVER BASIN ENERGY STUDY REGION

Siting Components and Variables	Weights			
	1st Round		2nd Round	
	Mean ($\bar{X}$)	Standard Deviation σ	Mean ($\bar{X}$)	Standard Deviation σ
Air Quality	9.01	1.67	9.15	1.04
Sulfur Dioxide (SO_2)	0.52	0.15	0.50	0.14
Total Suspended Particulates (TSP)	0.48	0.15	0.50	0.14
Ecological Systems and Land Use	7.55	1.79	7.62	1.55
Public Lands	0.20	0.10	0.20	0.10
Unique Natural Areas	0.27	0.12	0.37	0.17
Forest Land	0.19	0.08	0.17	0.08
Agricultural Land	0.34	0.10	0.29	0.11
Water Availability	3.79	1.91	3.34	1.94
Population Density	2.46	2.69	2.26	2.31
Seismic Suitability	0.97	2.93	0.86	1.93
	N=23		N=19	

Table 18. WEIGHTS FOR SITING COMPONENTS AND VARIABLES FOR NUCLEAR-FUELED ELECTRICITY GENERATING FACILITIES IN THE OHIO RIVER BASIN ENERGY STUDY REGION

	Weights			
	1st Round		2nd Round	
Siting Components and Variables *	Mean ($\bar{X}$)	Standard Deviation σ	Mean ($\bar{X}$)	Standard Deviation σ
Ecological Systems and Land Use	7.04	1.82	7.05	1.43
Public Lands	0.21	0.10	0.21	0.10
Unique Natural Areas	0.26	0.11	0.36	0.17
Forest Land	0.18	0.78	0.18	0.08
Agricultural Land	0.35	0.16	0.28	0.11
Water Availability	6.6	2.1	5.57	2.15
Population Density	8.5	2.06	8.86	1.28
Seismic Suitability	8.4	2.00	9.06	1.11
	N=23		N=19	

*Air quality was excluded from consideration in siting nuclear-fueled facilities.

1. Coal-based Scenarios, Base Case Environmental Controls

$$S_j = \frac{9.15\ [(0.5)\ X_{1j1} + (0.5)\ X_{2j1}] + 7.62\ [(0.20)\ X_{1j2} + (0.37)\ X_{2j2} + (0.17)\ X_{3j2} + (0.29)\ X_{4j2}] + 3.34(X_{1j3})}{9.15 + 7.62 + 3.34 + 2.26 + 0.86} \tag{5}$$

2. Coal-based Scenarios, Strict Environmental Controls

$$S_j = \frac{9.15\ [(0.5)\ X_{1j1} + (0.5)\ X_{2j1}] + 7.62\ [(0.20)\ X_{1j2} + (0.37)\ X_{2j2} + (0.17)\ X_{3j2} + (0.29)\ X_{4j2}] + 3.34\ (X_{1j3}) + 2.26\ (X_{1j4}) + 0.86\ (X_{1j5})}{9.15 + 7.62 + 3.34 + 2.26 + 0.86} \tag{6}$$

3. Nuclear Emphasis, Base Case Environmental Controls

$$S_j = \frac{7.05\ [(0.21)\ X_{1j2} + (0.36)\ X_{2j2} + (0.18)\ X_{3j2} + (0.28)\ X_{4j2}] + 5.57\ (X_{1j3}) + 8.86\ (X_{1j4}) + 9.06\ (X_{1j5})}{7.05 + 5.57 + 8.86 + 9.06} \tag{7}$$

In each case

S_j = the absolute suitability index for the jth county

X_{1j1} = numerical ranking for SO_2 in the Air Quality Component for the jth county

X_{2j1} = numerical ranking for TSP in the Air Quality Component for the jth county

X_{1j2} = numerical ranking for Natural, Scenic and Recreational Areas in the Land Use and Ecological Systems Component for the jth county

X_{2j2} = numerical ranking for Sensitive and Protected Environments in the Land Use and Ecological Systems Component for the jth county

X_{3j2} = numerical ranking for Agricultural and Ecological Productivity in the Land Use and Ecological Systems Component for the jth county

X_{4j2} = numerical ranking for Forest Lands Ownership and Management in the Land Use and Ecological Systems Component for the jth county

X_{1j3} = numerical ranking for the Water Availability Component for the jth county

X_{1j4} = numerical ranking for the Population Density Component for the jth county

X_{1j5} = numerical ranking for the Seismic Suitability Component for the jth county

All components and criteria are used to define site suitability in the coal-based scenarios with strict environmental control policies, whereas the seismic suitability and population density components are not included in defining base case environmental controls. The nuclear-based scenarios, which exclude the air quality component, assume current environmental control policies that apply to nuclear-fueled generating units. The county-level patterns of site suitability for each of the basic scenarios are significantly different.[11]

Coal-based, Base Case Environmental Control Scenarios

The coal emphasis, base case environmental control scenarios, have the largest number of counties with relatively high suitability indices (Figure 28), The most suitable counties border the Ohio River main stem and the lower reaches of its major tributaries upstream and downstream of Louisville, Kentucky. This reflects the importance of water availability relative to other siting components, such as air quality, which is defined by primary standards. Elsewhere, the majority of counties have better than average suitability (with scores ranging from 6 to 8). In general, counties in Illinois, Indiana, Ohio and Pennsylvania are more likely to be less suitable as sites than those in Kentucky and West Virginia. Land use and ecological system criteria are more important north of the Ohio River.

The majority of the counties in the ORBES region are candidate sites for coal-fired scenario unit additions under base case environmental control policies (Table 19 and Figure 29). Relatively few are excluded from consideration, as the exclusionary criteria are defined in a liberal manner. For example, an entire county must be designated a nonattainment area, or be in public lands, to be excluded from the list of candidate counties. This assumes that sites can be located in counties that contain nonattainment areas or acreages of public land. Siting is also restricted in counties (17) with > 1950 MWe scheduled for 1985, as the addition of a 650 MWe scenario unit would exceed the 2400 MWe maximum. The majority of the counties that are excluded are located along the Ohio River main stem north of Louisville, and in Ohio, Pennsylvania and West Virginia. However, the majority of the counties with the highest suitability scores are candidate counties.

Figure 28. **SITE SUITABILITY INDEX, COAL-FIRED SCENARIO UNIT ADDITIONS**

BASE CASE ENVIRONMENTAL CONTROLS

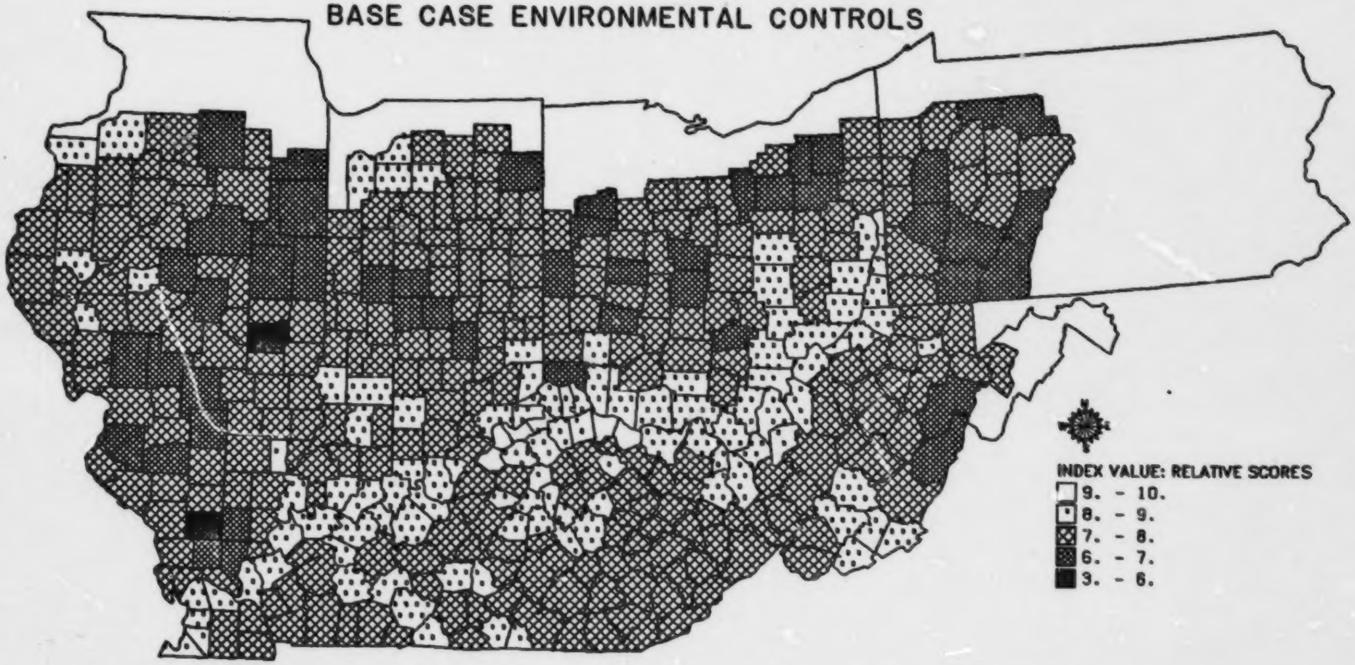


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Table 19. SUMMARY OF COUNTIES EXCLUDED AS SITES FOR COAL-FIRED SCENARIO UNIT ADDITIONS IN BASE CASE ENVIRONMENTAL CONTROL SCENARIOS

State Subregion	Air Quality				Public Lands[c]	Combined Total Excluded	Total ORBES Counties
	Violation of NAAQS[a]		PSD	Combined Total			
	SO_2	TSP	Class I[b] Areas				
ILLINOIS							85
INDIANA	2			2		2	83
KENTUCKY	5	6	2	9	2	10	120
OHIO	5			5		5	68
PENNSYLVANIA	1	1		1		1	19
WEST VIRGINIA	1	—	2	3	—	3	48
Total Counties	14	7	4	11	2	21	423

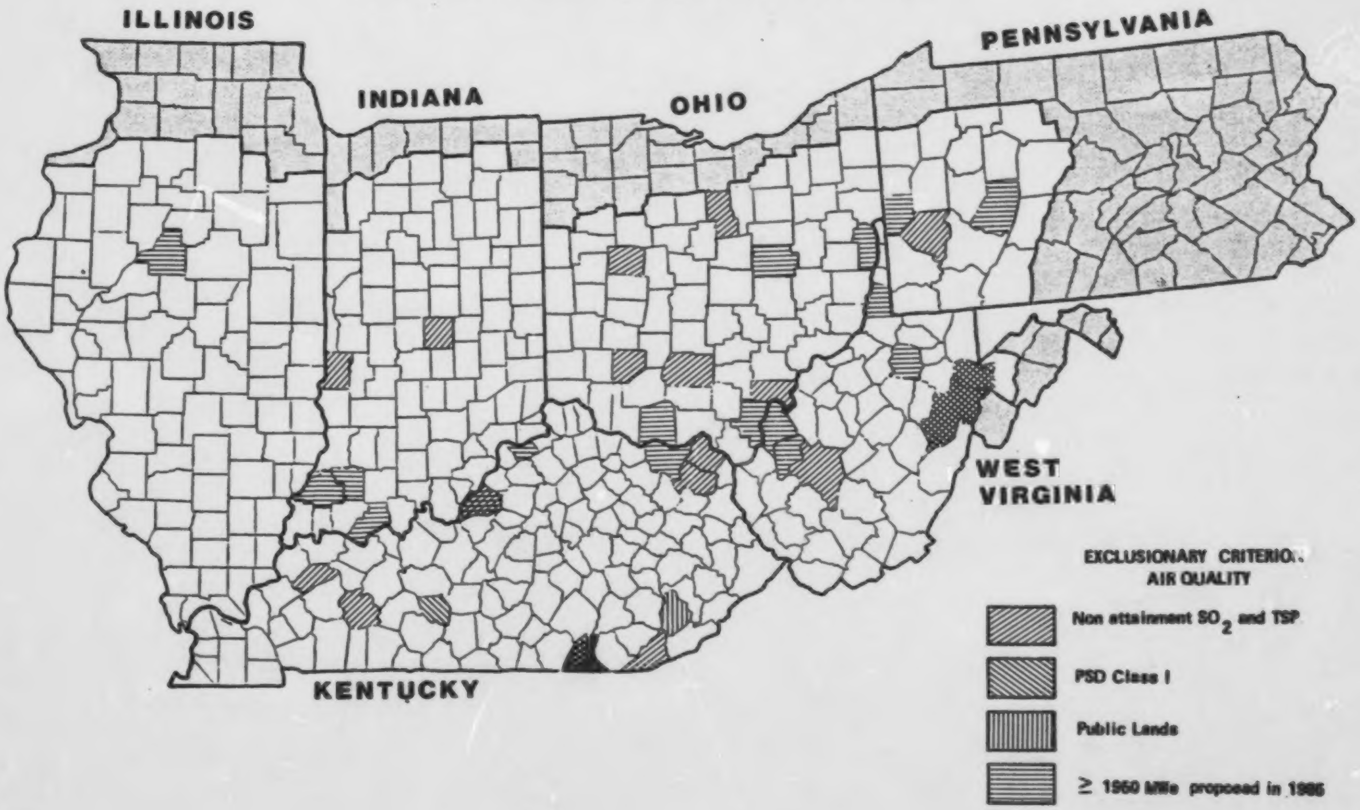
[a] County designated nonattainment area, primary standards.

[b] County contains mandatory Class I area.

[c] All of county in public lands; actual ownership.

Figure 29. **COUNTIES EXCLUDED AS SITES FOR COAL-FIRED SCENARIO UNIT ADDITIONS,**

BASE CASE ENVIRONMENTAL CONTROLS



Coal-based, Strict Environmental Control Scenarios

The site suitability indices for coal-based, strict environmental control scenarios are lower, and the geographical pattern is more complex (Figure 30). The sequence of highly suitable sites along the Ohio River main stem and tributaries is significantly reduced, and the extent of counties with lower suitability indices north of the Ohio River is expanded significantly, especially in Illinois. These changes are primarily the result of using secondary standards to define ambient air quality, with the seismic suitability and population distribution components adding constraints in selected counties.

The exclusionary criteria are defined more conservatively for strict environmental control policies (Table 20 and Figure 31). For example, a county is excluded if it contains a nonattainment area for SO_2 or TSP, or the majority of its area is in public lands, including the designated purchase area. Other exclusionary criteria are the same as in the base case. The net effect is to increase significantly the number of counties that are excluded from consideration as candidate sites, and to change the distribution of the counties that are available for scenario unit additions. Large portions of Ohio and Pennsylvania are excluded, as are counties along the Ohio River main stem and most metropolitan areas. TSP is the most important exclusionary criteria. In combination with the generally lower site suitability indices for strict control policies, the exclusionary criteria significantly reduce the choice of highly suitable sites to a few clusters of counties upstream of Cincinnati, Ohio; from Cincinnati to Louisville, Kentucky; and downstream of Louisville.

Nuclear Emphasis, Base Case Environmental Controls

The pattern of site suitability for the nuclear emphasis scenarios differ significantly from both of those that emphasize coal-fired generating units (Figure 32). The dominance of the seismic suitability and population distribution components is apparent, as well as the influence of ecological systems and land use criteria in central Illinois, Indiana and Ohio. Three areas have relatively high suitability indices. The most suitable counties are along the Ohio River main stem upstream from Louisville, Kentucky. Counties on major tributaries of the upper Ohio River, and in east central Kentucky, also have high suitability indices. Counties along the upper Illinois River in northwestern Illinois, and in northern Indiana, are also suitable sites.

Relatively few counties are excluded as sites for nuclear-fueled scenario unit additions (Table 22 and Figure 33). The majority of these are in seismic Zone III in the southwestern part of the region. Counties with the majority of their area in public lands and densely-populated counties that include the region's largest cities account for the remaining excluded counties. Large portions of the ORBES region, especially along the middle and upper Ohio River and its tributaries, have high suitability scores and are available as candidate sites for nuclear-fueled units.

Figure 30. **SITE SUITABILITY INDEX, COAL-FIRED SCENARIO UNIT ADDITIONS**

STRICT ENVIRONMENTAL CONTROLS

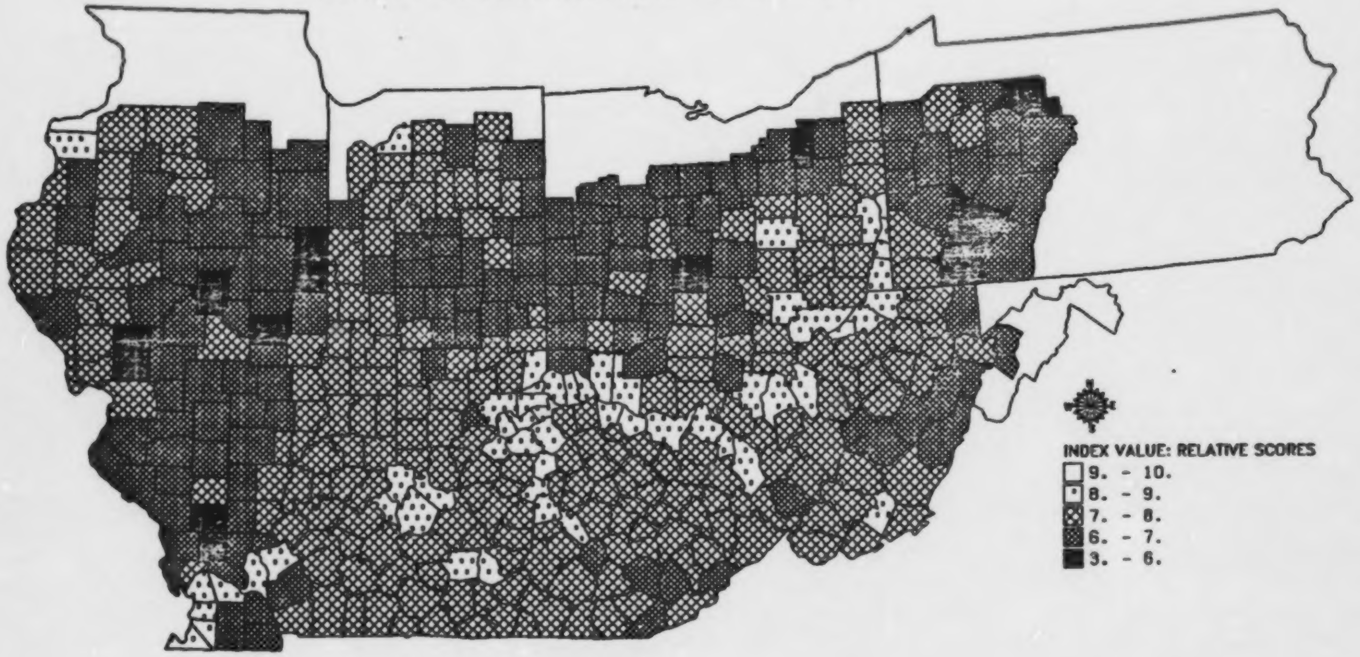


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Table 20. SUMMARY OF COUNTIES EXCLUDED AS SITES FOR COAL-FIRED SCENARIO UNIT ADDITIONS IN STRICT ENVIRONMENTAL CONTROL SCENARIOS

State Subregion	Air Quality				Public Lands[c]	Combined Total Excluded	Total ORBES Counties
	Violation of NAAQS[a]		PSD	Combined Total			
	SO_2	TSP	Class I[b] Areas				
ILLINOIS	3	19		19	4	22	85
INDIANA	3	8		8	4	12	83
KENTUCKY	9	15	2	19	9	27	120
OHIO	21	38		43	3	44	68
PENNSYLVANIA	5	8		9	1	10	19
WEST VIRGINIA	2	6	2	8	3	9	48
Total Counties	43	94	4	106	24	124	423

[a] County designated nonattainment area, primary standards.

[b] County contains mandatory Class I area.

[c] All of county in public lands; actual ownership.

Figure 31. **COUNTIES EXCLUDED AS SITES FOR COAL-FIRED SCENARIO UNIT ADDITIONS,**
STRICT ENVIRONMENTAL CONTROLS

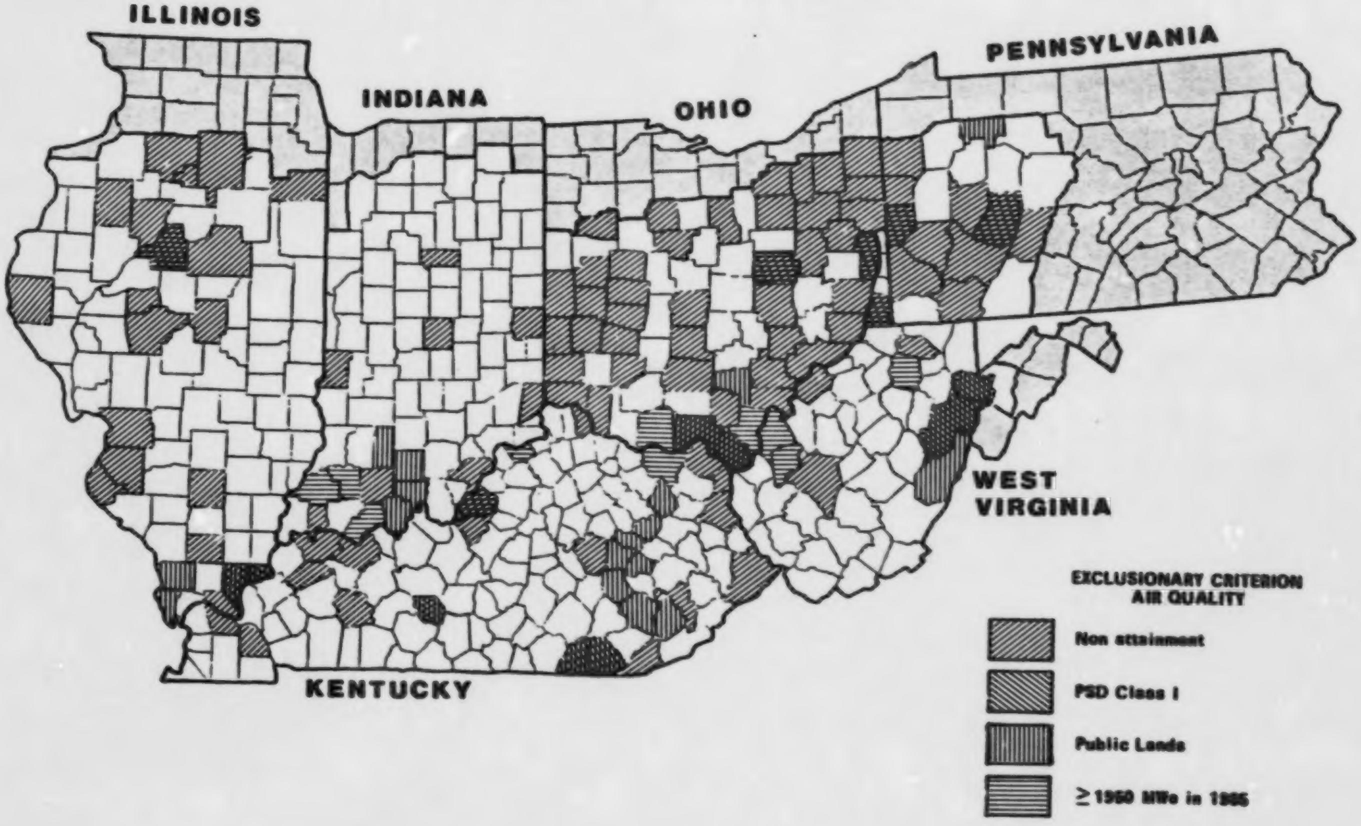
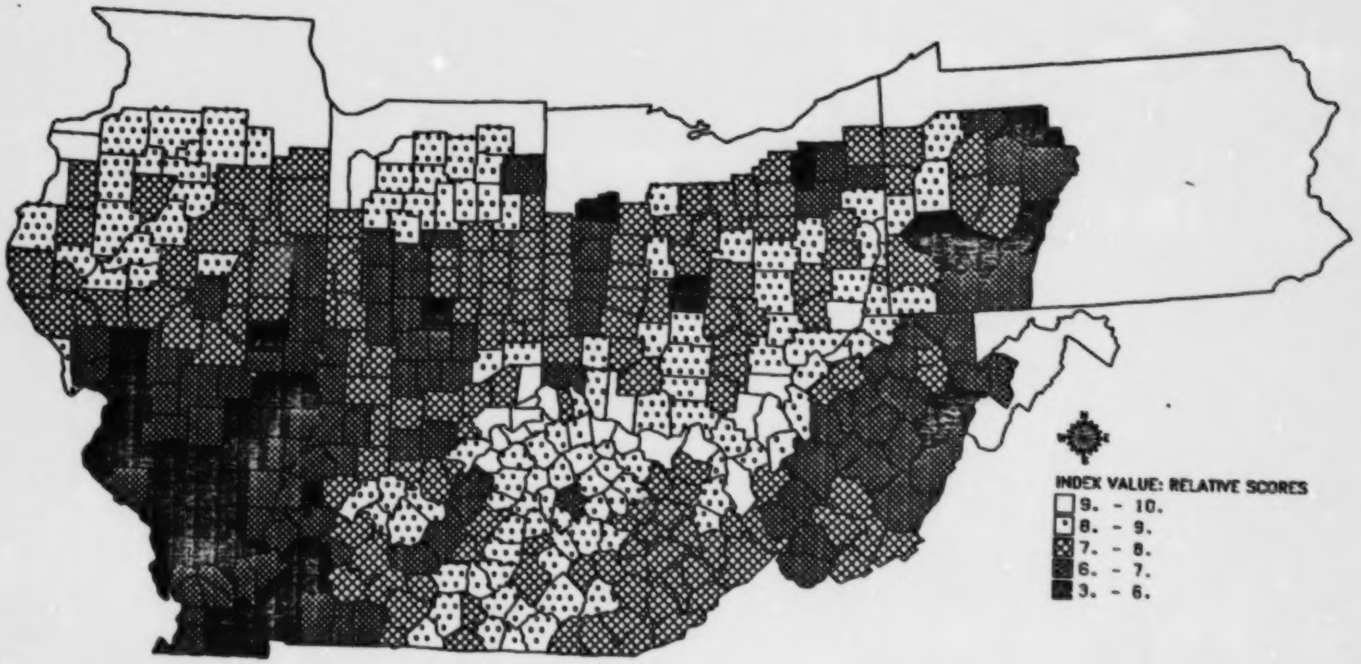


Figure 32. **SITE SUITABILITY INDEX, NUCLEAR-FUELED SCENARIO UNIT ADDITIONS**



PREPARED FOR OHIO RIVER BASIN ENERGY STUDY
BY CAGIS/UICC, FEBRUARY, 1980

Table 21. SUMMARY OF COUNTIES EXCLUDED AS SITES FOR NUCLEAR-FUELED SCENARIO UNIT ADDITIONS

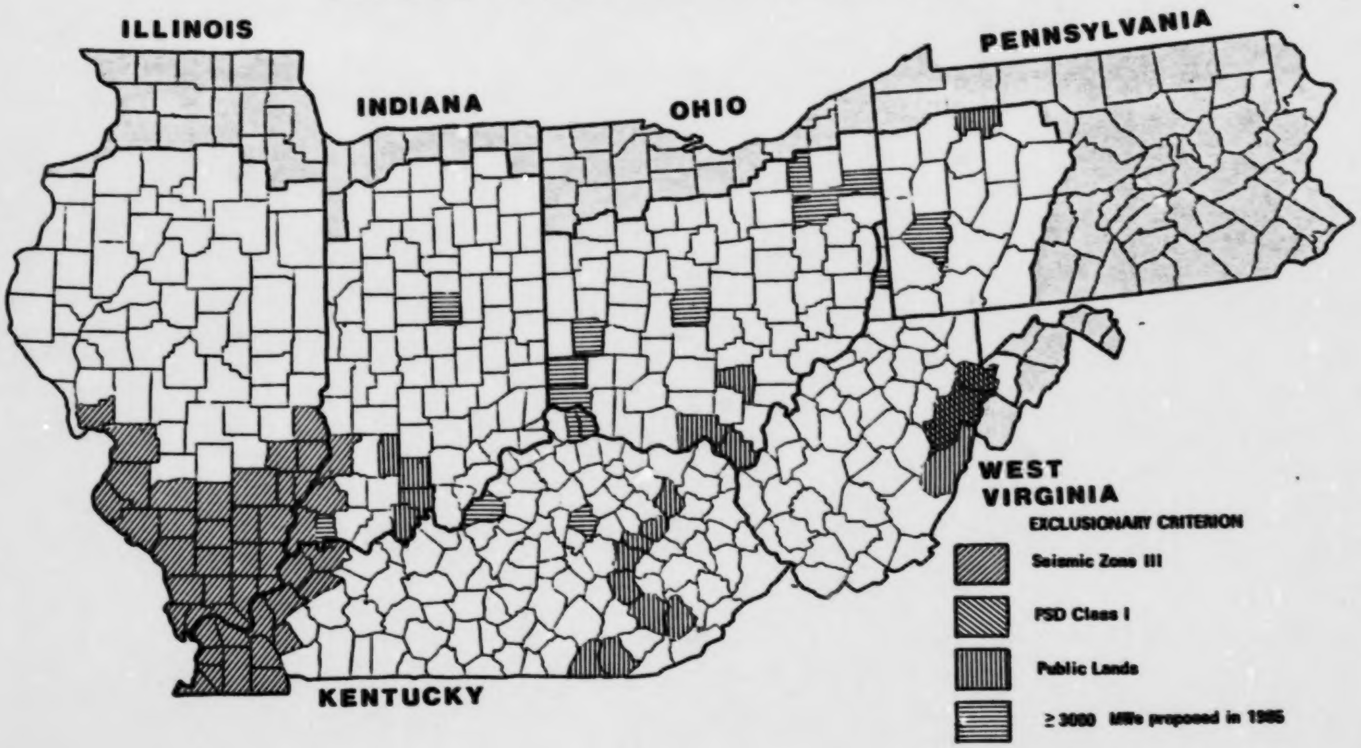
State Subregion	Seismic Suitability[a]	Population Density[b]	Public Lands[c]	Combined Total Excluded	Total ORBES Counties
ILLINOIS	28		4	28	85
INDIANA	4	2	4	9	85
KENTUCKY	14	4	9	27	120
OHIO		7	3	10	68
PENNSYLVANIA		1	1	2	19
WEST VIRGINIA		1	3	4	48
Total Counties	46	15	24	80	423

[a] Majority of county within seismic Zone III.

[b] County population density $\geq$ 500 persons per square mile.

[c] Majority of county in public lands; total area, including designated purchase area.

Figure 33. **COUNTIES EXCLUDED AS SITES FOR NUCLEAR-FUELED SCENARIO UNIT ADDITIONS**



FOOTNOTES

[1] The 'region' is defined relative to the site, and to attainment and nonattainment areas (McHugh, 1978).

[2] Cf. McHugh (1978). Air quality modeling, which was used to define nonattainment areas in Indiana, is a more conservative method that results in fewer, and smaller, areas than using measured data, such as in Illinois.

[3] Regional air quality issues are discussed by McLaughlin (forthcoming).

[4] The data are from the states' annual air quality reports for 1977, except Indiana, which was for 1977-1978.

[5] In calculating plume rise, the Holland and TVA-Concurve equation results were averaged for speeds ≤ 4 m/s; for > 4 m/s, the TVA-Concurve and Briggs equation are averaged. Such decision was made on the basis of a TVA plume rise report (TVA, 1968 and 1974).

Holland :

$$\Delta h = \frac{V_s d}{u} [1.5 + .0096 Q_h / V_s d]$$

TVA-Concurve:

$$\Delta h = 4.71 \frac{Q_h^{.444}}{u^{.694}}$$

Briggs :

$$\Delta h = \frac{114C\ F^{1/3}}{u} \qquad C = 1.58 - 41.4 \frac{\Delta\theta}{\Delta t}$$

$$F = gV_s d^2 (T_s - T_a)/4T_a$$

in each of these, Δ is in [m/s], V_s [m/s], d[m], u[m/s], Q_h[kj/s], θ(°K), Z(m) and $Q_n = 6.7 \times 10^4$ KJ/S

$Q_{SO_2} = 1.0 \times 10^9$ µg/S

$Q_{TSP} = 8.33 \times 10^7$ µg/S

H = stack height + Δh

$$\text{Steady-state } X_{max} = \frac{1.17 \times 10^8}{u \sigma_Y \sigma_z} \text{ for } SO_2$$

$$= \frac{4.87 \times 10^6}{u\sigma_Y \sigma_z} \text{ for particulate}$$

where X has the units $\mu g/m^3$.

[6] For a detailed discussion of the impacts of energy development in the ORBES region on land use and ecological systems, see: Randolph and Jones (forthcoming).

[7] To a certain degree, the definition of sensitive and protected environments depends on the way in which states identify natural areas; see: Randolph and Jones (forthcoming).

[8] Fletcher (1980) and USEPA (1977). See also the discussion in this report, Section 6, pp. 127-133.

[9] In addition to concern over the recurrence of such an event in the New Madrid seismic zone, the NRC has hypothesized that an equally large earthquake could occur in the Wabash Valley seismic zone. This conservative view toward seismicity in the Wabash Valley is documented in several letters from the NRC to Illinois Power Company with respect to the Clinton Power Plant which, at the time, was proposed for a site in De Witt County, Illinois. The NRC contends that the Wabash Valley fault zone is structurally connected with the New Madrid fault zone and, therefore, could experience an earthquake as large as those at New Madrid. The Illinois Power Company contends that the Rough Creek fault zone, which cuts across the trend of the Wabash Valley and New Madrid fault zones, separates the two into unrelated seismic zone. The outcome of this exchange was that the Clinton Safety Evaluation Report was modified by Supplement No. 1 and the plant is now being built with enhanced earthquake resistance.

[10] Similar techniques were used to collect information on the relative importance of siting criteria in ORNL's work with the Maryland Power Plant Siting Program (Dobson, 1979). ORNL used the weights for coal-fired plants from the Maryland study for siting capacity additions in the South for the National Coal Utilization Assessment (Davis et al, 1978). Delbecq, Van de Ven and Gustafson (1975) discuss the NGT and other Delphi techniques.

[11] The Wilcoxon Matched-Pairs Signed-Ranks test was used to determine whether or not the rank order of counties by site suitability was significantly different for the basic siting scenarios (i.e., coal emphasis base case and strict environmental controls; nuclear emphasis; and coal emphasis, very strict air quality and agricultural lands protection policy, both with dispersed siting). When compared with each other, the scenarios had significantly different site suitabilities at well below the one percent level of confidence.

SECTION 6

SITING PATTERNS FOR ORBES SCENARIOS

The siting patterns and on-line dates of capacity additions for the ORBES scenarios are designed to facilitate impact assessments of the interrelationships among different levels of energy demand, technology mix and environmental control policies. In the near-term, the schedule of sites and on-line dates for capacity additions in most scenarios follow announced utility plans. The number and type of scenario unit capacity additions that are necessary to meet final demand in the year 2000 are added after 1985 according to the ORBES siting model.

Two basic groups of scenarios are considered.[1] The first assumes that all scenario unit additions will be coal-fired. No nuclear-fueled units are sited except those that the utilities had announced in 1975. Scenario 2, which assumes base case environmental control policies and other current conditions, is the point of reference for those scenarios that emphasize coal-fired electrical generation. The second group emphasizes fuel substitution and conservation. One scenario assumes an emphasis on nuclear-fueled generation, whereas others assume that other fuels, or conservation, will dominate energy supply and demand after 1985. A third group of scenarios derived from Scenario 1 simulate very strict air quality policies, and an agricultural lands protection policy. These are developed for purposes of special impact assessments.

COAL EMPHASIS, CONVENTIONAL TECHNOLOGY

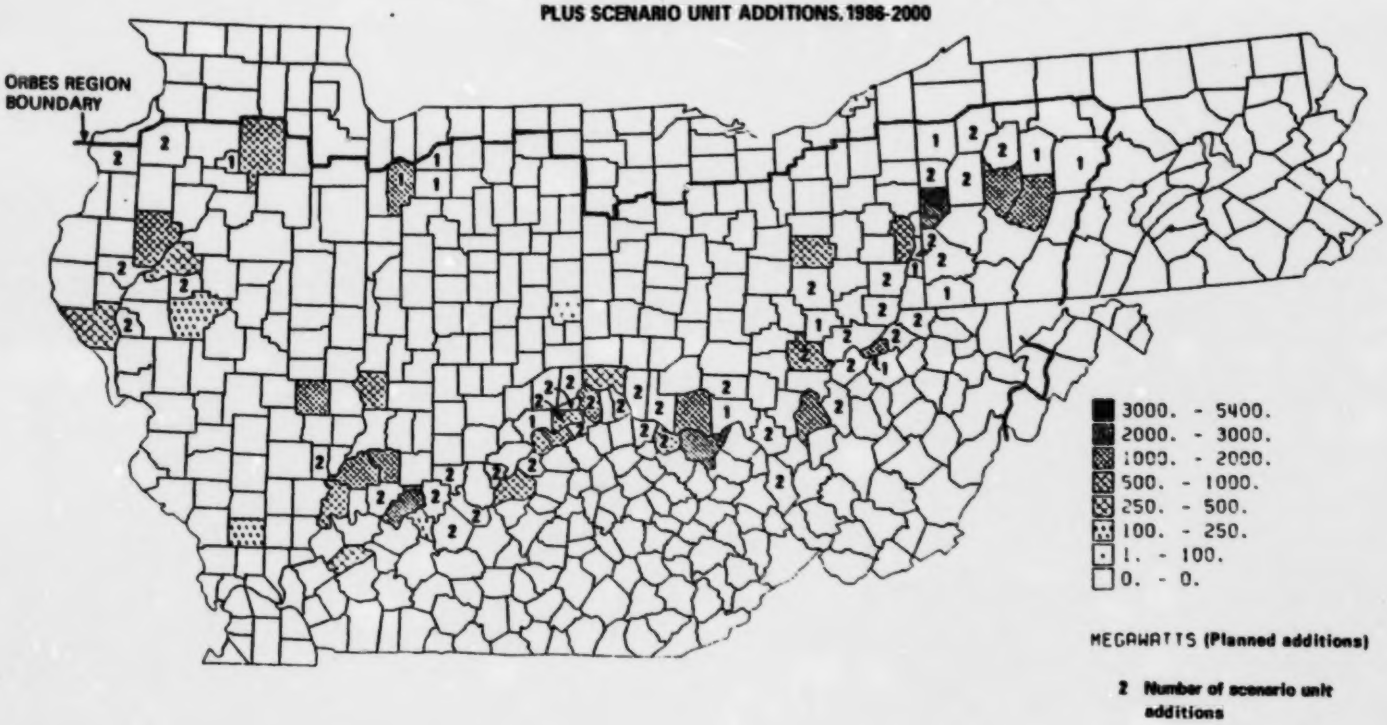
Scenario 2: Base Case Environmental Controls

The majority of the scenario unit additions that are required to meet electricity production in the year 2000 are sited in or adjacent to counties that have existing and announced generating capacity (Figure 34).[2] This results in the expansion of coal-fired generating units along the Ohio River main stem upstream from Louisville, Kentucky and Cincinnati, Ohio; along the upper Ohio River main stem in West Virginia and the coal fields of southeastern Ohio; and in counties bordering the Allegheny and Monongahela Rivers in western Pennsylvania. Scenario units are also added to existing or planned concentrations in the lower Illinois River basin and at the confluence of the Wabash River and the Ohio River. This scenario assumes continuation of current trends in policies that affect siting coal-fired units, especially with regard to environmental controls. Consequently, the scenario units are expected to be located in proximity to existing and planned additions to coal-fired generating capacity, in areas that have sufficient resources to support new units.

Figure 34. **SCENARIO 2: CONVENTIONAL TECHNOLOGY, BASE CASE CONTROLS**

TOTAL PROPOSED COAL-FIRED GENERATING CAPACITY ADDITIONS, 1976-85

PLUS SCENARIO UNIT ADDITIONS, 1986-2000



The geographical distribution of the capacity additions also suggests that current environmental impacts may continue, if not intensify. The issue of air quality is a case in point. At local scale, capacity additions are located in or adjacent to counties that may already have significant problems of air quality degradation. Questions about rights to resources, especially such as those raised by plants that are located close to one another across state boundaries, may also increase. At regional scale, the majority of the scenario unit additions are along the Ohio River main stem, with significant additions to the concentration of plants in the eastern part of the region. Because the new additions are in line with the prevailing winds, long-range pollutant transport, acid precipitation and related issues should be examined carefully.

No nuclear-fueled scenario unit additions are sited in the scenarios that emphasize long-term dependence on coal-fired generating capacity. The nuclear-fueled units that are in service, under construction or announced in utility plans are included in the assessment siting patterns (Figure 35).

Scenario 1: Strict Environmental Controls

In Scenario 1, changes in environmental policy with respect to the quality issue, have the most significant effect on siting scenario unit additions (Figure 36). The geographical pattern is more dispersed, with a larger number of units located away from concentrations of existing and planned generating capacity. The change is especially pronounced in the eastern part of the region. In Ohio, scenario units are located along tributaries to the Ohio River, rather than the main stem; and in Pennsylvania, they are along the Allegheny River. By comparison, the distribution of scenario unit additions changes relatively little in the western part of the region. The majority of scenario unit additions in Indiana and Kentucky are sited in or adjacent to counties that have existing and announced electricity generating capacity. A few units are displaced from the Ohio River main stem to its tributaries. In Illinois, the number of units that are located in counties bordering the lower Wabash River increases.

Compared with the base case scenario, the change to strict environmental controls results in a shift in the geographical distribution of the coal-fired scenario unit additions away from areas that have problems meeting air quality standards to areas that have relatively meager water resources. In many instances, especially in Ohio, some type of augmentation may be necessary to provide the cooling water necessary for generating units. Water availability is clearly a major economic and environmental issue. The cost of constructing cooling ponds and reservoirs raises economic questions whereas water quality impacts and land use change, especially in counties that have agricultural land resources, are related issues. In addition, the question of the effect of a more dispersed siting pattern in the eastern part of the region on ambient air quality remains a central concern.

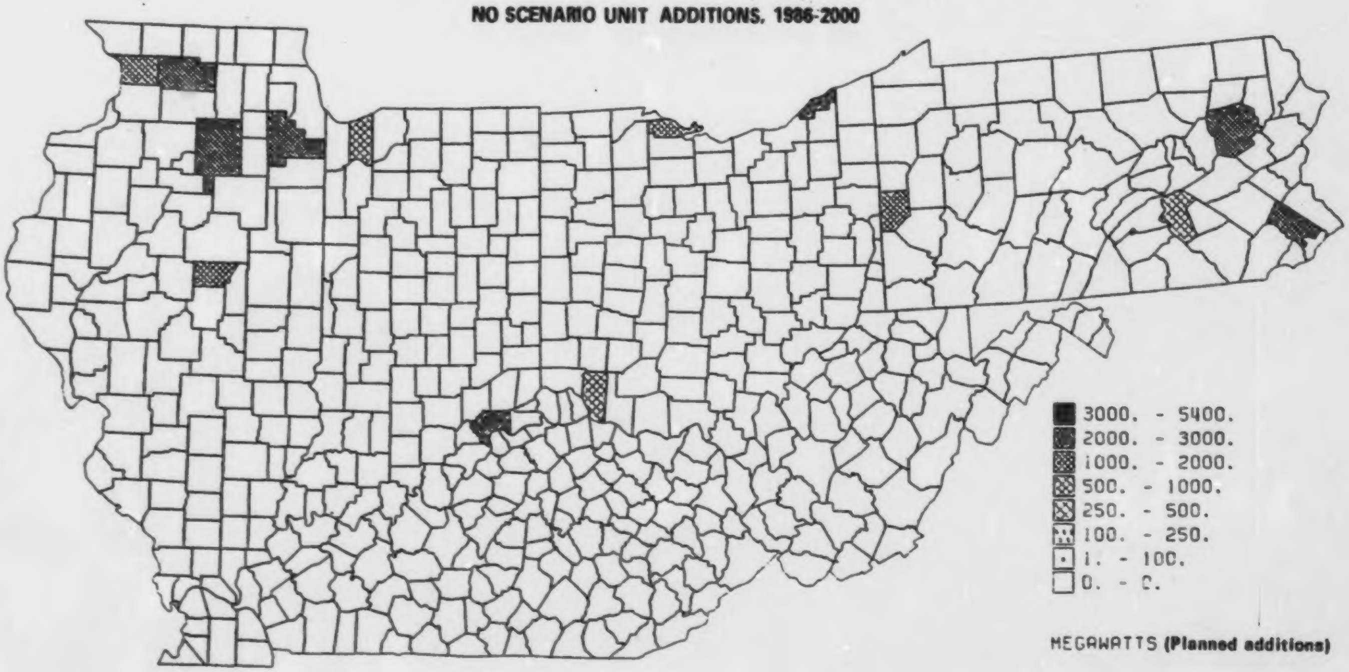
Scenario 7a and 7b: Very High Energy Growth

This scenario assumes an average annual growth rate in electricity that is 3.1 times higher than in the base case. This requires siting an additional 69 scenario unit additions with a 35 year useful life, or an additional 49 units

Figure 35. **SCENARIO 2: CONVENTIONAL TECHNOLOGY, BASE CASE CONTROLS**

TOTAL PROPOSED NUCLEAR GENERATING CAPACITY ADDITIONS, 1976-85

NO SCENARIO UNIT ADDITIONS, 1986-2000

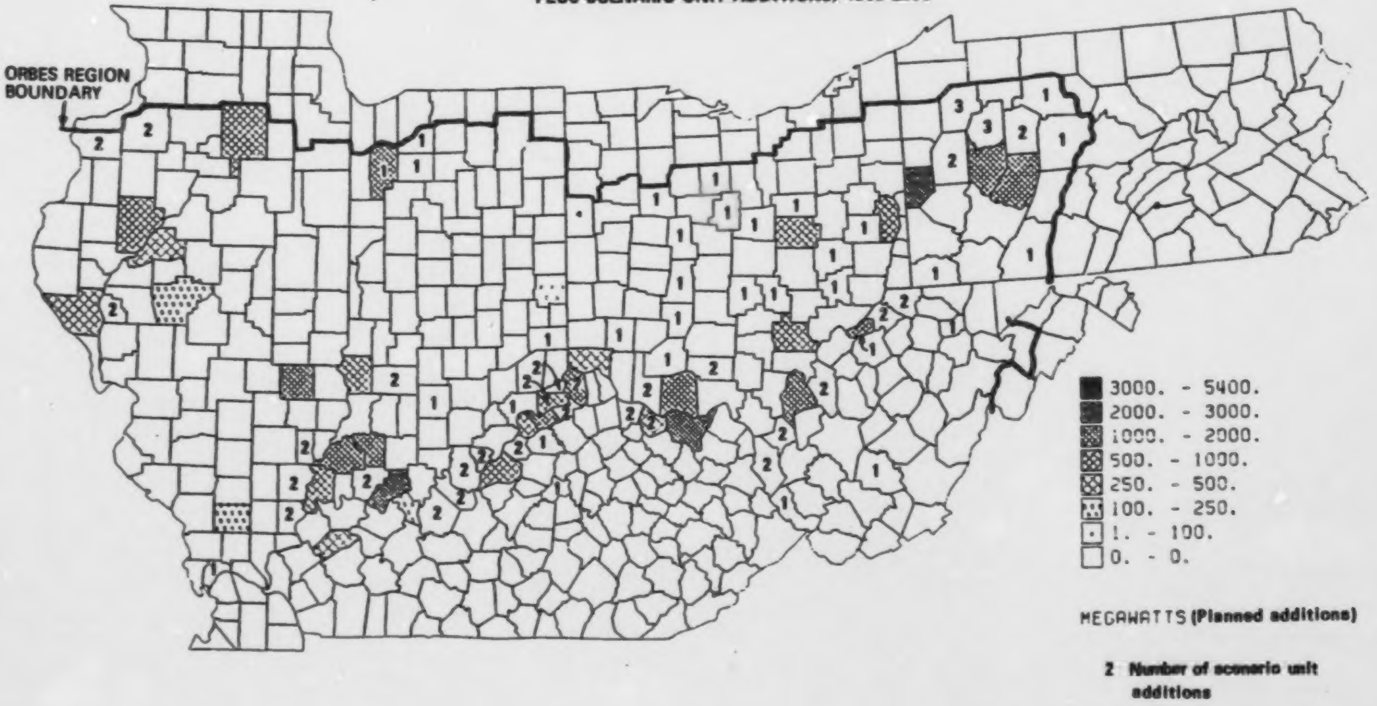


SOURCE: ERC ELECTRICAL GENERATING UNIT INVENTORY
PREPARED FOR THE ENERGY RESOURCES CENTER
BY CAGIS UICC AUGUST, 1975

Figure 36. **SCENARIO I: CONVENTIONAL TECHNOLOGY, STRICT CONTROLS**

TOTAL PROPOSED COAL-FIRED GENERATING CAPACITY ADDITIONS, 1976-85

PLUS SCENARIO UNIT ADDITIONS, 1986-2000



if the useful life assumption is increased to 45 years. Environmental control policies are the same as in the base case scenario. In order to simplify the assessment of impacts associated with a very high electrical energy growth rate, the incremental number of scenario units is added to the siting pattern for Scenario 2.[3]

The siting pattern for this scenario, with 35 year useful plant life, has three distinctive characteristics (Figure 37). First, the majority of the scenario units are added to counties that are already identified in Scenario 2 as sites for capacity additions. Additional units are sited, sometimes to the maximum of 2600 MWe per county. Second, scenario units are sited in areas of meagre water resources, again primarily in the eastern part of the region. Third, some units that are assigned to Ohio are sited in West Virginia and Kentucky. Under strict environmental controls, the large number of scenario units that might be allocated to Ohio do not have an adequate number of counties in the state with sufficient resources to support them even if units are located in areas of meagre water supplies.

The siting pattern for the high electricity growth scenario with 35 year useful plant life combines the characteristics of the base case and strict environmental controls, with the additional feature of siting excess capacity out-of-state in the eastern part of the region. If the useful plant life is changed to 45 years, no scenario unit additions are sited out-of-state and relatively few are in areas of meager water resources (Figure 38). The geographical distribution of the planned plants and scenario unit additions is the difference between what might result from adding the scenario units necessary to meet a very high electrical growth rate, under current conditions and strict environmental controls, and from adding a decade to the useful life of each generating unit in order to reduce the number of new units required.

Scenario 2a: Coal-fired Export

The coal export scenario specifies that coal-fired units will supply the additional 20,000 MWe of installed generating capacity in the ORBES region that is dedicated to export to the northeastern states. This requires siting 31 coal-fired scenario units in addition to those needed for Scenario 2. Otherwise, the scenario policies are the same as in the base case.

In siting the scenario unit additions that are dedicated to export, two assumptions were made:

1. The costs of transmitting electricity from the ORBES region to the northeast will be minimized.

   Consequently, candidate counties in the eastern part of the ORBES region (eastern Kentucky, Ohio, Pennsylvania and West Virginia) are favored sites. They are also located close to major coal reserves.

2. Utilities will prefer to add generating capacity dedicated to export to existing sites (either announced or designated in the scenario) rather than develop new sites.

Figure 37. SCENARIO 7a: 35 YEAR LIFE
CONVENTIONAL COAL EMPHASIS, BASE CASE, HIGH ELECTRICAL ENERGY GROWTH
TOTAL PROPOSED COAL-FIRED GENERATING
CAPACITY ADDITIONS, 1976-85
PLUS SCENARIO UNIT ADDITIONS
1986– 2000

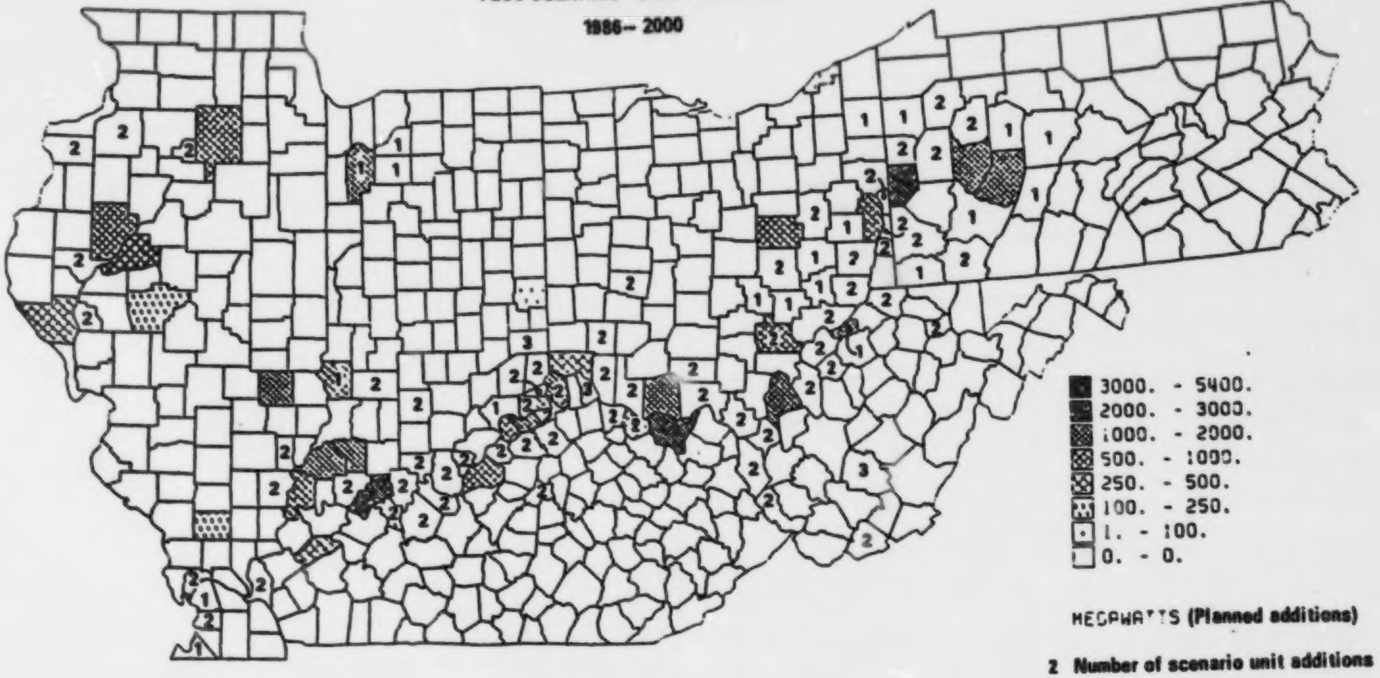
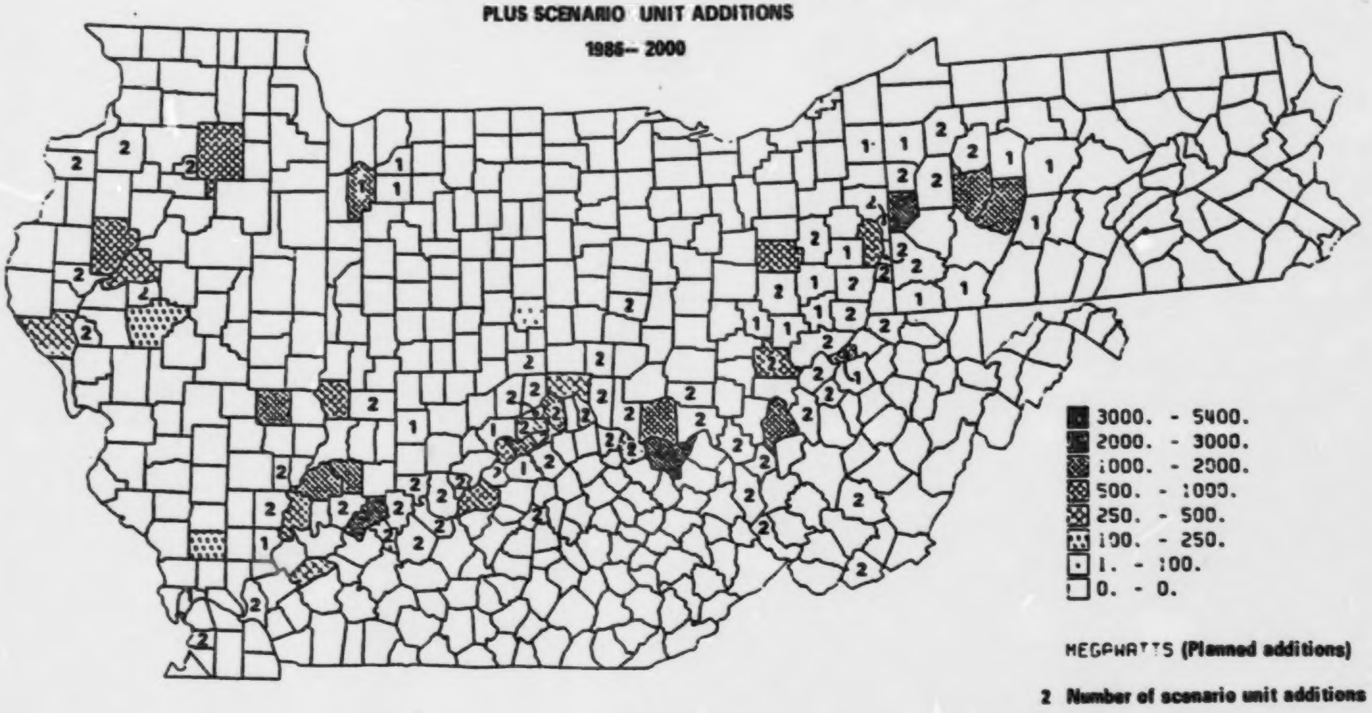


Figure 38. SCENARIO 7b: 45 YEAR LIFE
CONVENTIONAL COAL EMPHASIS, BASE CASE, HIGH ELECTRICAL ENERGY GROWTH
TOTAL PROPOSED COAL-FIRED GENERATING
CAPACITY ADDITIONS, 1976-85
PLUS SCENARIO UNIT ADDITIONS
1986– 2000



Electricity dedicated to export is not intended to serve local demand.

The 31 additional units are allocated to eastern Kentucky, Ohio, Pennsylvania and West Virginia roughly in proportion to each state subregion's share of the region's projected net exports in 1986 (Page, 1979, Appendix B). Within each state subregion, the capacity additions are allocated first to existing stations that can accomodate additional capacity (assuming a maximum of 2600 MWe per county) and then to new counties consistent with the order of site selection followed in Scenario 2. This procedure allows the impacts associated with export to be calculated as incremental changes without changing the basic geography of ORBES electricity production in the year 2000.

The siting patterns in the western part of the ORBES region are the same as in Scenario 2 (Figure 39). In the eastern part of the region, scenario units are added in or adjacent to counties that have existing or planned additions in Scenario 2. These are located along the middle and upper Ohio River; in the coalfields of southeastern Ohio; and along the Allegheny River in Pennsylvania. The effect is to increase significantly the geographical concentration of coal-fired units that will come on-line after 1985 in the eastern part of the region. Although the siting pattern is similar to those of high energy growth scenarios, the additional scenario units are located only in the eastern part of the region, and are concentrated in fewer counties.

FUEL SUBSTITUTION AND CONSERVATION

Scenario 3: Alternate Technology

In Scenario 3, alternate technologies are assumed to supply a portion of the region's electricity production in the year 2000 that is projected by the base case scenario. The result is that 66 rather than 95 coal-fired scenario unit additions will be sited after 1985. Base case environmental controls also apply to this scenario, as well as others in this set. Consequently, the siting pattern will be similar to Scenario 2 except that fewer counties will be involved.[4]

Coal-fired scenario unit additions are sited in 39 of the 54 counties identified in Scenario 2 (Figure 40). The less suitable counties are excluded, and the concentration of coal-fired electric generation is reduced somewhat along the Ohio River main stem. Any changes in impacts that result from siting fewer scenario unit additions can be determined by comparison with Scenario 2. These changes can be attributed indirectly to the substitution of alternate technologies to produce electricity, although any impacts directly associated with these technologies cannot be assessed as they are not assigned county locations.

Scenario 4: Natural Gas Emphasis

In Scenario 4, the large-scale substitution of natural gas as a fuel for electricity generation is the reason for the significant reduction in the number of coal-fired scenario unit additions that are to be sited. The 34 units are located in 21 counties, including those that are most suitable as sites

Figure 39

SCENARIO 2a:
CONVENTIONAL TECHNOLOGY, BASE CASE CONTROLS, COAL-FIRED EXPORT
TOTAL PROPOSED COAL-FIRED GENERATING
CAPACITY ADDITIONS, 1976-85
PLUS SCENARIO UNIT ADDITIONS, 1986-2000

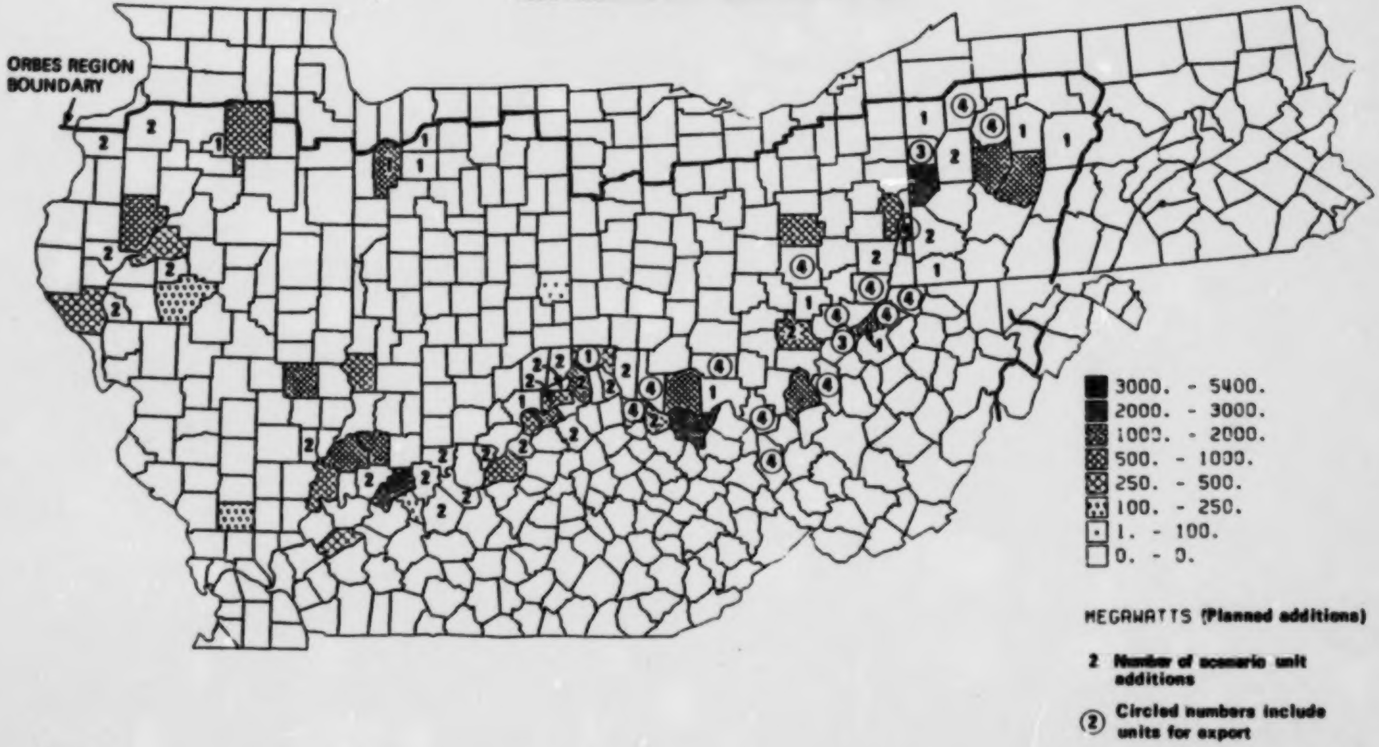


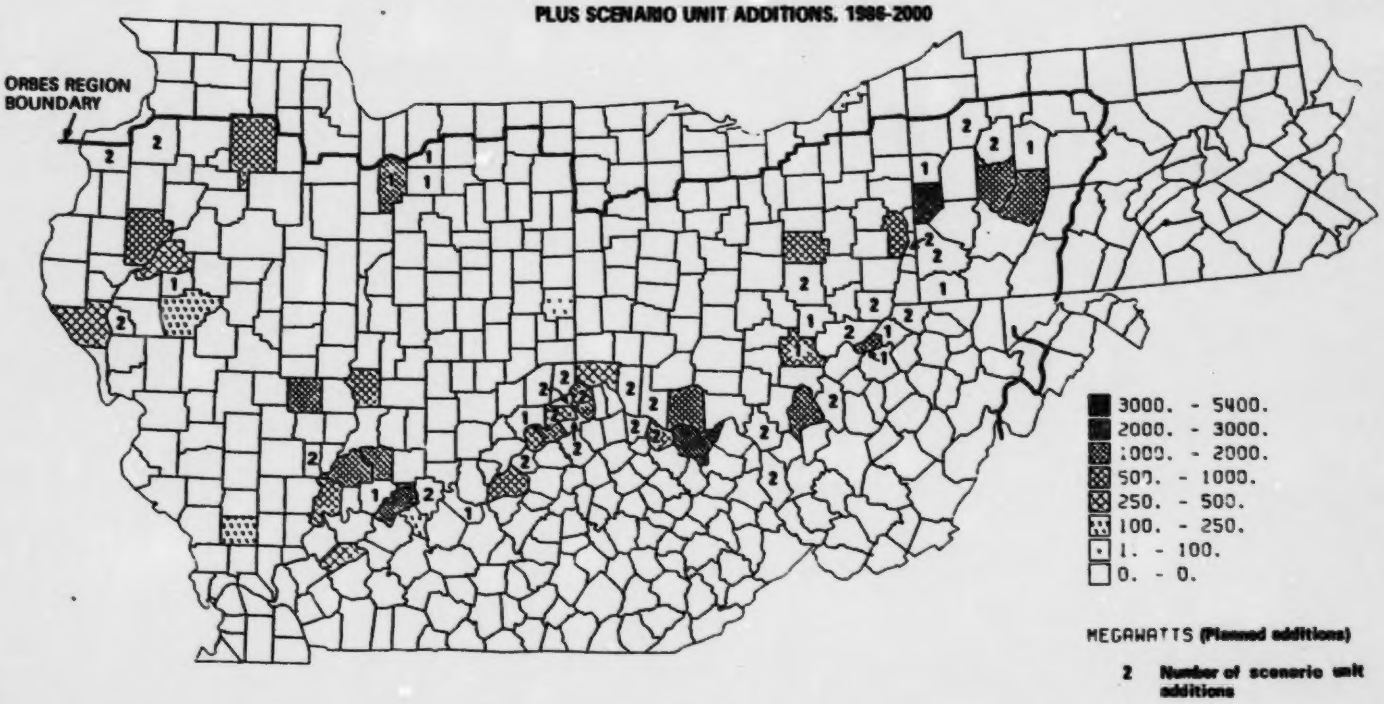
Figure 40

SCENARIO 3:

ALTERNATE TECHNOLOGY, BASE CASE CONTROLS

TOTAL PROPOSED COAL-FIRED GENERATING CAPACITY ADDITIONS, 1976-85

PLUS SCENARIO UNIT ADDITIONS, 1986-2000



for coal-fired plants. Given the environmental control policies, this represents a "better" siting pattern than in the other scenarios in the sense that the counties selected for scenario unit additions have higher suitability indices.

The geographical concentration of coal-fired scenario unit additions is significantly reduced (Figure 41). In fact, the persistence of the cluster of coal-fired units along the Ohio River main stem upstream from Louisville, Kentucky and Cincinnati, Ohio is the most prominent feature of the pattern. No scenario unit additions are located along the main stem downstream of Louisville; and the concentration of new units along the upper Ohio is significantly reduced. None of the units that is added in Illinois is along the Illinois River. The impact of the substitution of natural gas for coal as a fuel for electricity generation can be assessed to the extent that it results in fewer coal-fired scenario unit additions being sited in the ORBES region after 1985.

Scenario 6: Conservation (Very Low Energy Growth)

Energy conservation results in the most significant change in the siting patterns for coal-fired capacity additions when compared with the base case scenario. Because of very low energy growth rates, only 20 additional units are required. These are located in 13 counties, each of which has the highest site suitability rank of candidate counties in each respective state subregion (Figure 42). The middle Ohio River main stem continues to be the core area for capacity additions, but fewer units and counties are involved.

The geographical distribution of the proposed coal-fired capacity additions clearly dominates the siting pattern for this scenario. Because other fuels (except nuclear) and technologies are not used to produce electricity, the changes in impacts that result from having a relatively small number of coal-fired scenario unit additions should be more readily identifiable.

Scenario 2c: Nuclear Emphasis

The siting pattern for Scenario 2c is dominated by nuclear-fueled scenario unit additions after 1985. The distribution of the few coal-fired scenario unit is similar to that of Scenario 4, Alternate Technologies. The distribution of the nuclear-fueled scenario unit additions is based upon the site suitability model for that fuel type. No nuclear-fueled units are sited in Kentucky and West Virginia. This assumes that the current policy of locating only coal-fired generating capacity in these two states will continue. In other state subregions, nuclear-fueled scenario unit additions are allocated with preference to counties having existing or announced sites for nuclear-fueled units that can be expanded. This assumes that utilities will prefer to locate additional units at sites that can physically accomodate additional capacity rather than risk the political and economic costs that might be associated with developing new sites. The additions are allocated to existing and announced sites so that the total site capacity does not exceed that specified by Burwell, Ohanian and Weinberg (1979) or 4000 MWe, whichever is less.

Figure 41

SCENARIO 4:
CONVENTIONAL TECHNOLOGY, NATURAL GAS EMPHASIS, BASE CASE CONTROLS
TOTAL PROPOSED COAL-FIRED GENERATING
CAPACITY ADDITIONS, 1976-85
PLUS SCENARIO UNIT ADDITIONS, 1986-2000

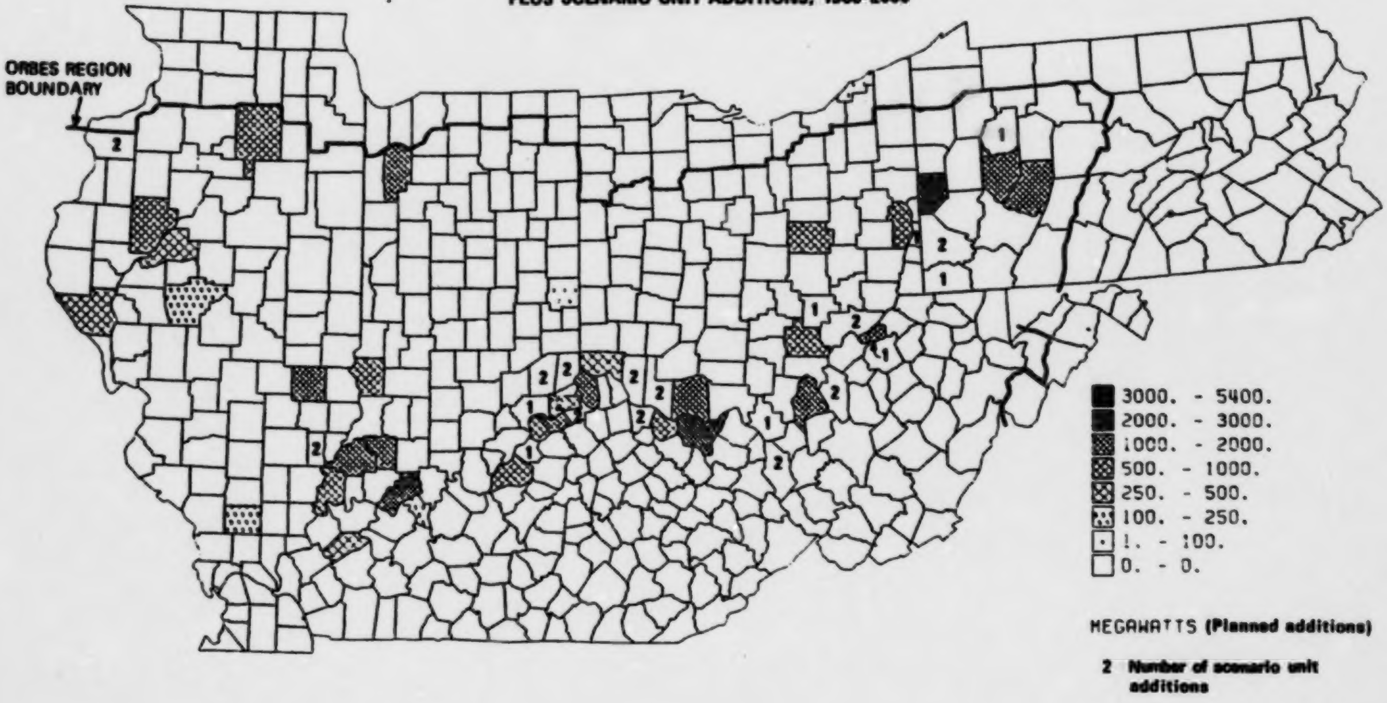
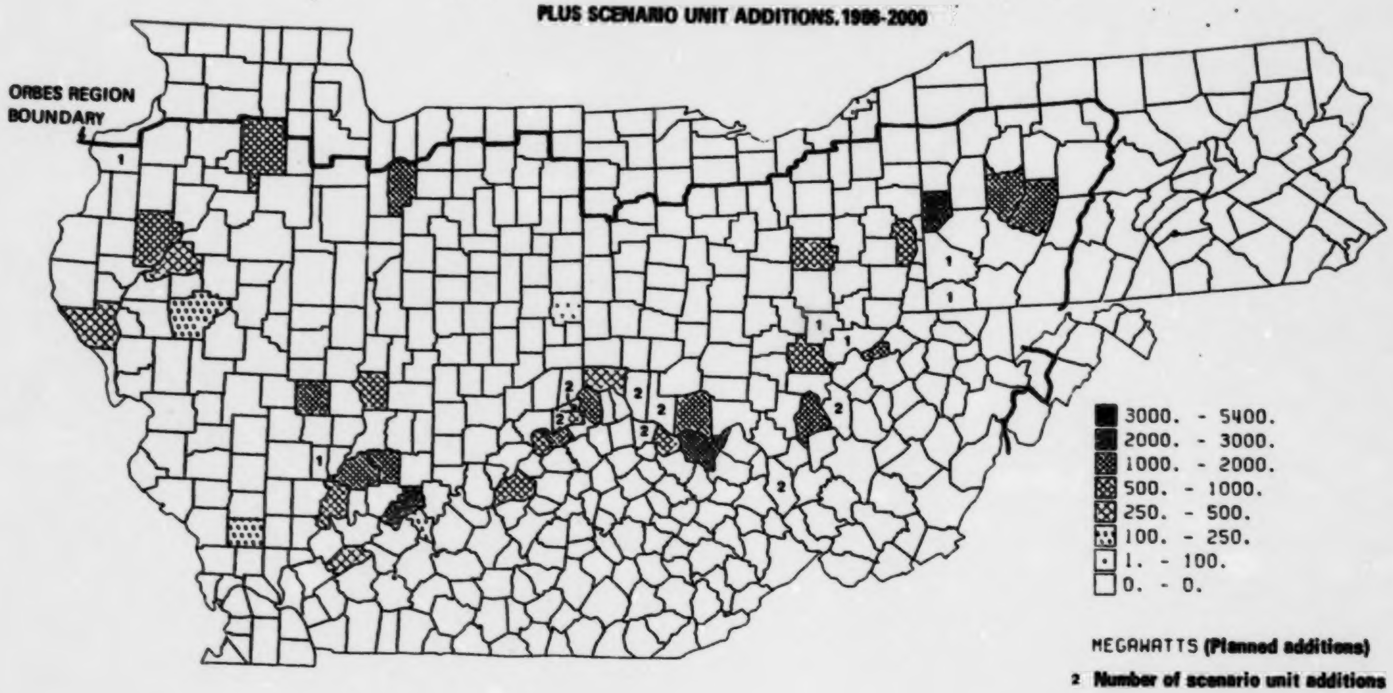


Figure 42

SCENARIO 6:
CONVENTIONAL TECHNOLOGY, BASE CASE CONTROLS, VERY LOW ENERGY GROWTH

TOTAL PROPOSED COAL-FIRED GENERATING CAPACITY ADDITIONS, 1976-85

PLUS SCENARIO UNIT ADDITIONS, 1986-2000



The nuclear-fueled scenario unit additions are concentrated in the western part of the ORBES region near existing and planned units (Figure 43). The majority are in northwestern Illinois, where additions are sited in counties along the middle and upper Illinois River, the Rock River, and the Mississippi River. The counties are either in or adjacent to Commonwealth Edison's service area; they include two of the alternate sites that Commonwealth Edison evaluated in the Environmental Impact Statement for its Savannah plant in Carroll County.[5] In Indiana, the nuclear-fueled scenario unit additions are along the Ohio River main stem in the southeast corner of the state with a single unit in the northeast, where the environment is similar to, but less suitable than, areas in northwestern Illinois.

The geographical distribution of nuclear-fueled scenario unit additions in Illinois and Indiana outline the basic environmental issues of nuclear siting throughout the ORBES region. Excluded from areas of high seismic risk and population density, the plant locations shift to predominantly rural counties that have significant acreages of prime agricultural land, ecologically sensitive areas, and problems of water availability. Illinois Power Company's Clinton Plant (DeWitt County, Illinois) is an example of the tradeoffs between seismic risk and water availability. On the other hand, reactions from Putnam County residents to Commonwealth Edison's designation of the county as an "alternate" site for the Savannah plant shows concern over the issue of prime agricultural land. In Indiana, the location of nuclear-fueled scenario unit additions along the Ohio River main stem adds significantly to the concentration of electrical generating capacity in that area.

SITING PATTERNS FOR SPECIAL POLICY ANALYSIS

Scenario 1a: Very Strict Air Quality Controls

The basic siting pattern for Scenario 1 is based upon a moderate interpretation of strict environmental controls, especially those concerning air quality. Whereas the general effect is a more dispersed siting pattern for scenario unit additions in the upper Ohio River Basin, new units in the middle and lower basin are clustered in counties bordering the main stem in Indiana, Kentucky and southwestern Ohio. A review of the siting pattern suggests that the configuration of scenario unit additions may still contribute to air quality problems at subregional and regional scale. Some of the additions are located in counties which, according to 1977 NADB monitor data, had less than the full PSD increment available (Appendix C). Other units are located relatively close to one another, especially along the Ohio River main stem, which raises the issue of separation distance policy within the interstate pollution abatement provisions of the 1977 Clean Air Act Amendments. Consequently, additional scenarios incorporate very strict air quality control policies designed to create a more dispersed spatial distribution of new electricity generating units.[6]

Procedure

The siting pattern for this scenario is produced by making selected changes in the siting model used in the strict environmental controls of Scenario 1.

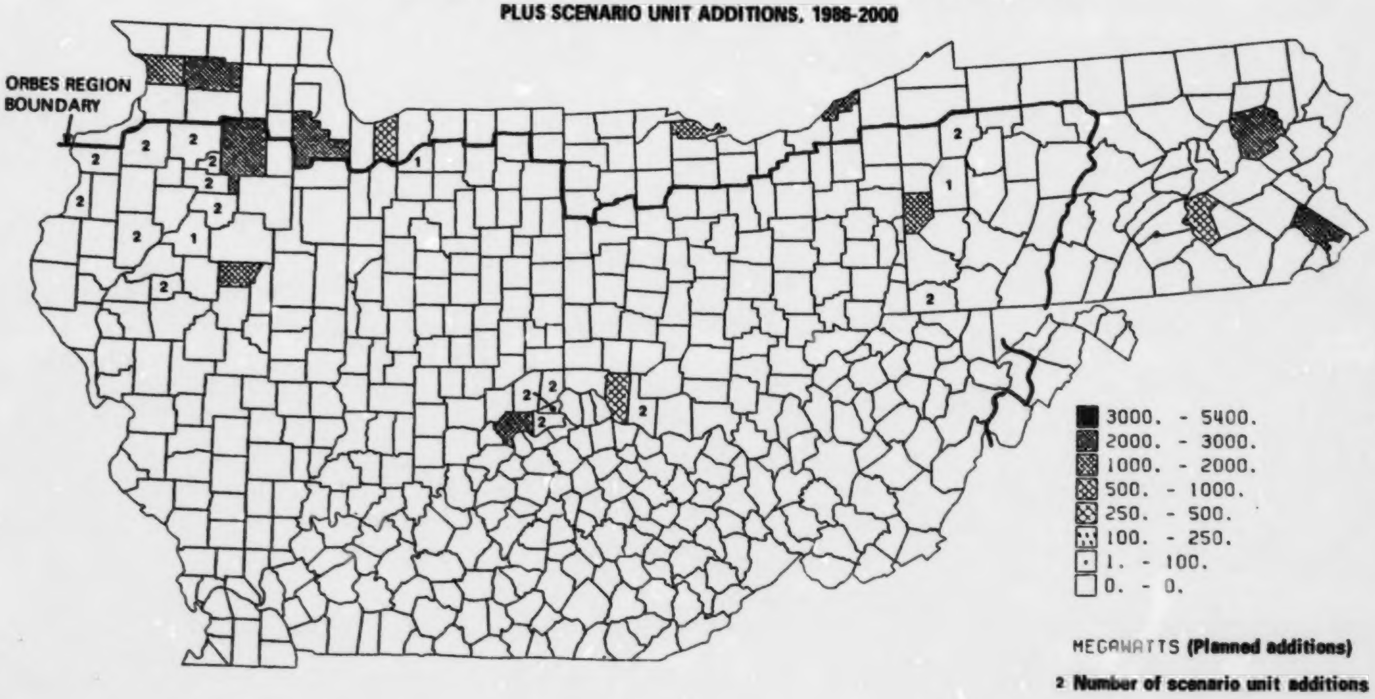
Figure 43

SCENARIO 2c:

CONVENTIONAL TECHNOLOGY, BASE CASE CONTROLS, NUCLEAR EMPHASIS

TOTAL PROPOSED NUCLEAR GENERATING
CAPACITY ADDITIONS, 1976-85

PLUS SCENARIO UNIT ADDITIONS, 1986-2000



Changes in exclusionary criteria for air quality assume a more stringent policy on air pollution performance standards; and changes in the relative importance of several components of the siting model alter the suitability of candidate counties as sites for coal-fired generating unit additions. The allocation procedure for scenario units additions is also modified consistent with the increased environmental constraints for siting decisions.

The changes are:

1. Exclude counties with violations of NAAQS for SO_2 and TSP and/or less than full PSD increment available, for 24 hour and annual secondary standards (Appendix C).

   This assumes a more stringent USEPA policy on air pollution performance standards, including the addition of the PSD increment as an exclusionary criterion for new stationary sources.[7]

2. Increase the importance value of the Air Quality component from the Delphi value of 9.15 to the maximum, 10.

   This is consistent with the increased role of air quality in evaluating the suitability of a site for generating unit additions.

3. Increase the importance value of the Land Use and Ecological Systems component from the Delphi value of 7.62 to the maximum, 10.

   The importance of this component in evaluating site suitability will increase because of the indirect impacts of air quality upon productivity, and the land use conflicts that result from the water requirements of scenario unit additions.

4. Decrease the importance value of the Water Availability component by 50 percent, from the Delphi value of 3.34 to 1.67.

   The importance of water availability in evaluating the site suitability will decrease as more generating units are located away from large rivers and streams in areas that will require constructing large reservoirs for cooling water supplies. The 50 percent figure is arbitrary.

5. Allocate scenario unit additions with preference to counties having announced utility sites which can be expanded.

   Utilities will prefer to locate unit additions on sites which can accomodate additional capacity, especially under very strict environmental controls.[8]

Exclusionary Screening and Site Suitability

Changing the exclusionary criteria significantly decreases the number of candidate counties and changes their geographical distribution (Table 22 and Figure 44). The total number of excluded counties increased from 124 to 199. The majority of the 64 additional counties had less than the full PSD increment available for TSP. The geographical distribution of non-attainment counties and those counties excluded because of PSD criteria are significantly different. However, the majority of the excluded counties failed to meet both the 24 and the annual air quality standards. The use of the annual standard resulted in a net addition of only 14 counties to the list.

Compared with Scenario 1, changes in the air quality exclusionary criteria had their greatest impact upon the geography of candidate counties along the middle and lower Ohio River main stem and its major tributaries in West Virginia and Kentucky. The valley of the Monongahela (except for Greene County) and the Kanawah, and large parts of the Licking and Green Rivers are excluded from consideration. Along the Ohio River main stem, only 22 counties are candidate sites for new electricity generating units. The changes are less dramatic elsewhere. The majority of the additional counties excluded in Indiana and Ohio were in the central eastern part of each state. Eastern Ohio has only one county available for siting. However, the geography of candidate counties did not change significantly in either Illinois or Pennsylvania.

Changes in the weights for the Air Quality, Land Use and Ecological Systems, and Water Availability components also produced significantly different site suitability patterns for the scenarios (Figure 45). The magnitude of change is greatest among the middle and lower ranking counties in states that have large numbers of counties in the ORBES region. This has significant implications for siting, as many of the top-ranking counties are excluded as sites for scenario unit additions under the very strict interpretation of air quality criteria.

Siting Pattern

The siting pattern developed under the environmental constraints of very strict air quality controls has the same number of scenario unit additions as specified for Scenario 1. The geographical distribution of the scenario unit additions, however, is significantly different (Figure 46). The majority of the counties in which capacity additions are sited either were not selected in Scenario 1 (22 of 64) or are in a different position in the schedule (27 of 64). The most significant changes are in Indiana and Kentucky, where the clusters of "new" units along the middle and lower Ohio River main stem are dispersed along the major tributaries.

In Indiana, the dispersed siting pattern is in response to significant changes in county site suitability indices and the fact that a large number of counties are included in ECAR's utility site inventory. The majority of the utility sites are in counties that also have high suitability indices. Only three counties (four units) were displaced because of the changes in exclusionary criteria. However, changes in exclusionary criteria displaced 11 units in Kentucky away from the main stem to counties with lower water availability scores. Ten of the 11 Kentucky counties in which scenario units are located are not on the list for Scenario 1.

Table 22. SUMMARY OF COUNTIES EXCLUDED AS SITES FOR COAL-FIRED SCENARIO UNIT ADDITIONS IN SCENARIOS 1a AND 1b: VERY STRICT AIR QUALITY CONTROLS, AND IN SCENARIOS 1c AND 1d: AGRICULTURAL LANDS PROTECTION POLICY

State Subregion	Air Quality						Public Lands[c]	Class I and II Soils[d]	Combined Total Excluded		Total ORBES Counties
	Non-attainment				PSD	Combined Total[b]			Scenarios 1a and 1b	Scenarios 1c and 1d	
	Violation of NAAQS[a]		Less than Full PSD Increment Available[a]		Class I Areas						
	SO_2	TSP	SO_2	TSP							
ILLINOIS	2	17	1	11		20	4	54	24	66	85
INDIANA	3	10	3	15		18	4	50	22	62	83
KENTUCKY	1	39	2	45	2	60	10	6	68	70	120
OHIO	3	43	9	41		50	3	29	52	64	68
PENNSYLVANIA	1	8	1	3		8	1		9	9	19
WEST VIRGINIA	1	12	4	8	12	10	3		13	13	48
Total Counties	11	129	20	123	6	166	25	139	188	284	423

SOURCE: Appendix C.

[a] 24 hour and annual secondary standards.

[b] Counties that meet more than one exclusionary air quality criterion are counted only once.

[c] Majority of county in public lands; total area, including designated purchase area.

[d] Majority of total area of county in Class I and II soils.

[e] Counties that meet more than one exclusionary criterion are counted only once.

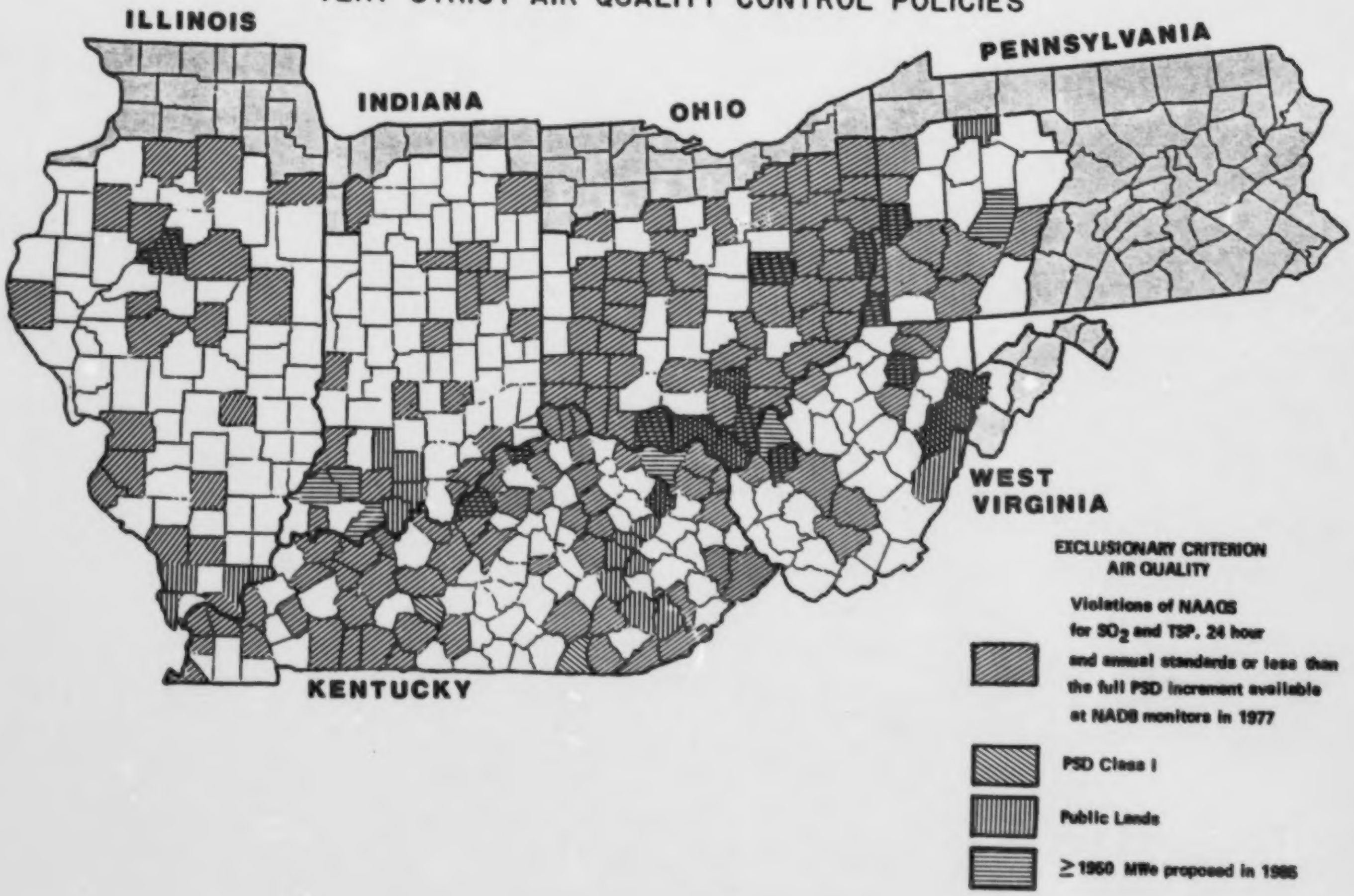
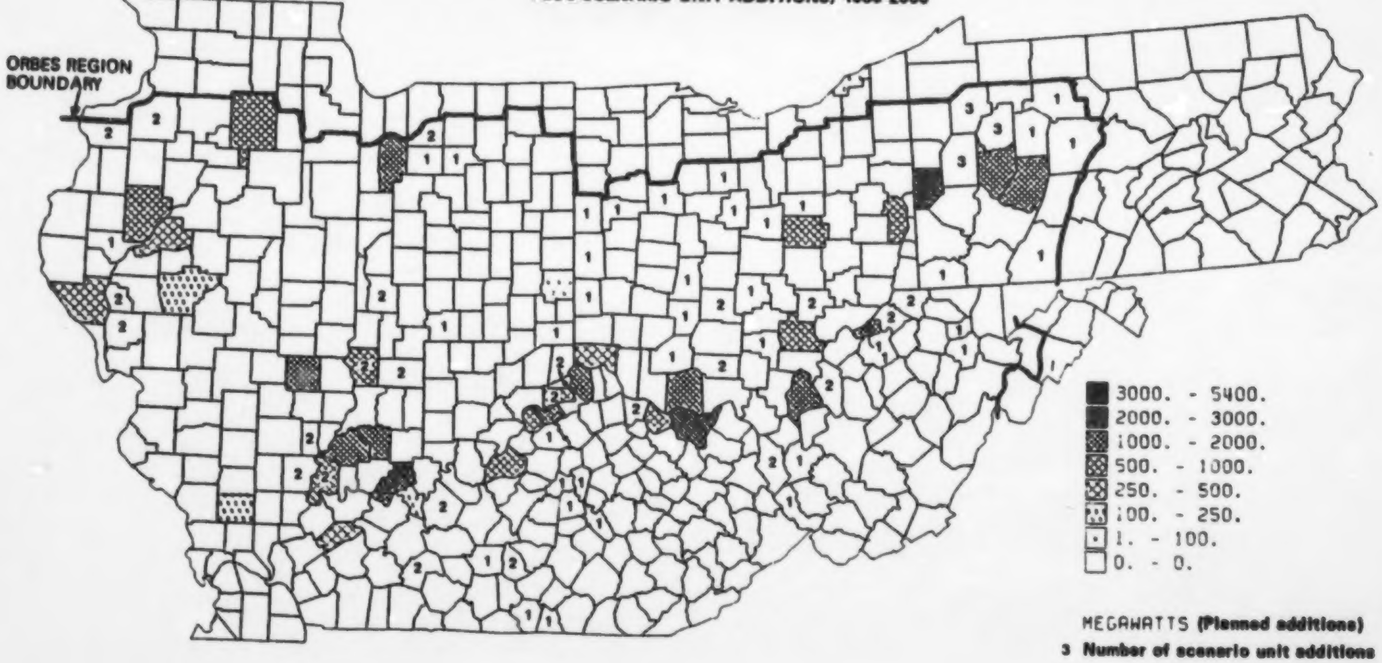

ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
WEST VIRGINIA
KENTUCKY
EXCLUSIONARY CRITERION AIR QUALITY
Violations of NAAQS for SO_2 and TSP, 24 hour and annual standards or less than the full PSD increment available at NADB monitors in 1977
PSD Class I
Public Lands
≥ 1950 MWe proposed in 1985

Figure 44. COUNTIES EXCLUDED AS CANDIDATE SITES: SCENARIOS IA AND IB VERY STRICT AIR QUALITY CONTROL POLICIES

Figure 45

SCENARIO IA:
VERY STRICT AIR QUALITY CONTROLS, DISPERSED SITING
TOTAL PROPOSED COAL-FIRED GENERATING
CAPACITY ADDITIONS, 1976-85
PLUS SCENARIO UNIT ADDITIONS, 1986-2000



Changes in siting patterns in other ORBES states are relatively minor. In Illinois, scenario units are added to counties along the lower Illinois River rather than the Ohio River. This is the result of changes in county suitability indices and the addition of Greene County as a future utility site.[9] No units are displaced because of changes in exclusionary criteria. In West Virginia, the scenario unit additions continue to be located along the Ohio River main stem as there are sufficient counties with high suitability indices to accomodate capacity additions. Stability is also characteristic of the siting patterns and schedules in Ohio and Pennsylvania, as each scenario has the same limited number of candidate counties with similar site suitability indices.

The siting pattern for very strict air quality controls suggests increased environmental conflicts between air quality, water availability, and land use and ecological systems impacts. The relocation of scenario unit additions in Indiana and Kentucky to counties with relatively meager water resources means that, with conventional technologies, reservoirs and ponds may be necessary to provide the cooling water for coal-fired plants in four of the six ORBES states. The land use requirements for conversion will increase, which increases the probability of conflicts with other types of land use, including agriculture and ecological systems.

Scenario 1c: Agricultural Lands Protection

Agricultural land is a significant environmental resource in the ORBES region. Its conversion to other uses because of energy development activities, whether surface mining of coal or the location of new conversion activities, is a source of conflict.[10] If very strict air quality standards are enforced (as in Scenarios 1a and 1b), conflicts associated with the location of conversion facilities are likely to increase because more scenario unit additions will be located in counties where reservoirs may be necessary to provide adequate cooling water. Agricultural lands protection policies are concerned with such conflicts, especially where prime farmlands are involved. Scenario 1c assumes that such policies are enforced with respect to siting electrical generating capacity additions.

Procedure

The siting pattern for this scenario is produced by making selected changes in the siting model for Scenario 1. Some of these are the same as changes made for the very strict air quality scenario. Others specifically relate to an agricultural lands protection policy.

The changes are:

1. Exclude counties with violations of NAAQS for SO_2 and TSP and/or less than the full PSD increments available, for 24 hour and annual secondary standards (Appendix A).
2. Exclude counties that have the majority (50 percent or more) of their land area in Class I and II soils.

This is consistent with the assumption that prime farm land is the most important agricultural lands resource.

3. Increase the importance value of the Class I and II soils from the Delphi value of 0.29 to the maximum, 1.0.

   This is also consistent with the assumption that prime farm land is the most important agricultural lands resource.

4. Increase the importance value of the Land Use and Ecological Systems component from the Delphi value of 7.62 to the maximum, 10.0.

   This is consistent with the agricultural lands protection policy.

5. Allocate scenario unit additions with preference to counties having announced utility sites that can be expanded.

   Utilities will prefer to locate unit additions on sites that can physically accomodate additional capacity, especially under very strict air quality and land use controls. Future land purchases could be a difficult issue, especially where agricultural lands are involved.

Exclusionary Screening and Site Suitability

The addition of prime farmland as an exclusionary criterion significantly decreases the number of candidate counties and changes their geographical distribution, especially in the western part of the region (Table 22, Figure 46). The total number of excluded counties increases from 188 to 284. Most of the 96 additional counties are in Illinois (42), Indiana (40) and Ohio (12). The effect is to exclude scenario unit additions from a broad wedge of counties across northern Illinois and Indiana into western Ohio. A smaller cluster of excluded counties is in southwestern Indiana and along the lower Wabash River in Illinois.

Changes in the weights for Class I and II soils, as well as for the Land Use and Ecological Systems Component, also produced significantly different site suitability patterns for the scenarios (Figure 47, 48). Counties along the Ohio River main stem and other rivers are less suitable although, in most cases, the amount of farmland is too limited to place them in the lower half of the list of candidate counties. Conversely, the relative suitability position of other counties is increased. These are located in the coal producing areas of southern Illinois and Indiana, and southeastern Ohio. Changes in site suitability indices of Kentucky, Pennsylvania and West Virginia counties are minor.

Scenario 1c: Agricultural Lands Protection Policy

The scenario unit additions in Illinois, Indiana and Ohio are located in counties that do not have the majority of their area in prime agricultural lands. The majority are located in the southern part of each state, but not

Figure 46. **COUNTIES EXCLUDED AS CANDIDATE SITES:**
SCENARIOS IC AND ID, AGRICULTURAL LANDS PROTECTION POLICY

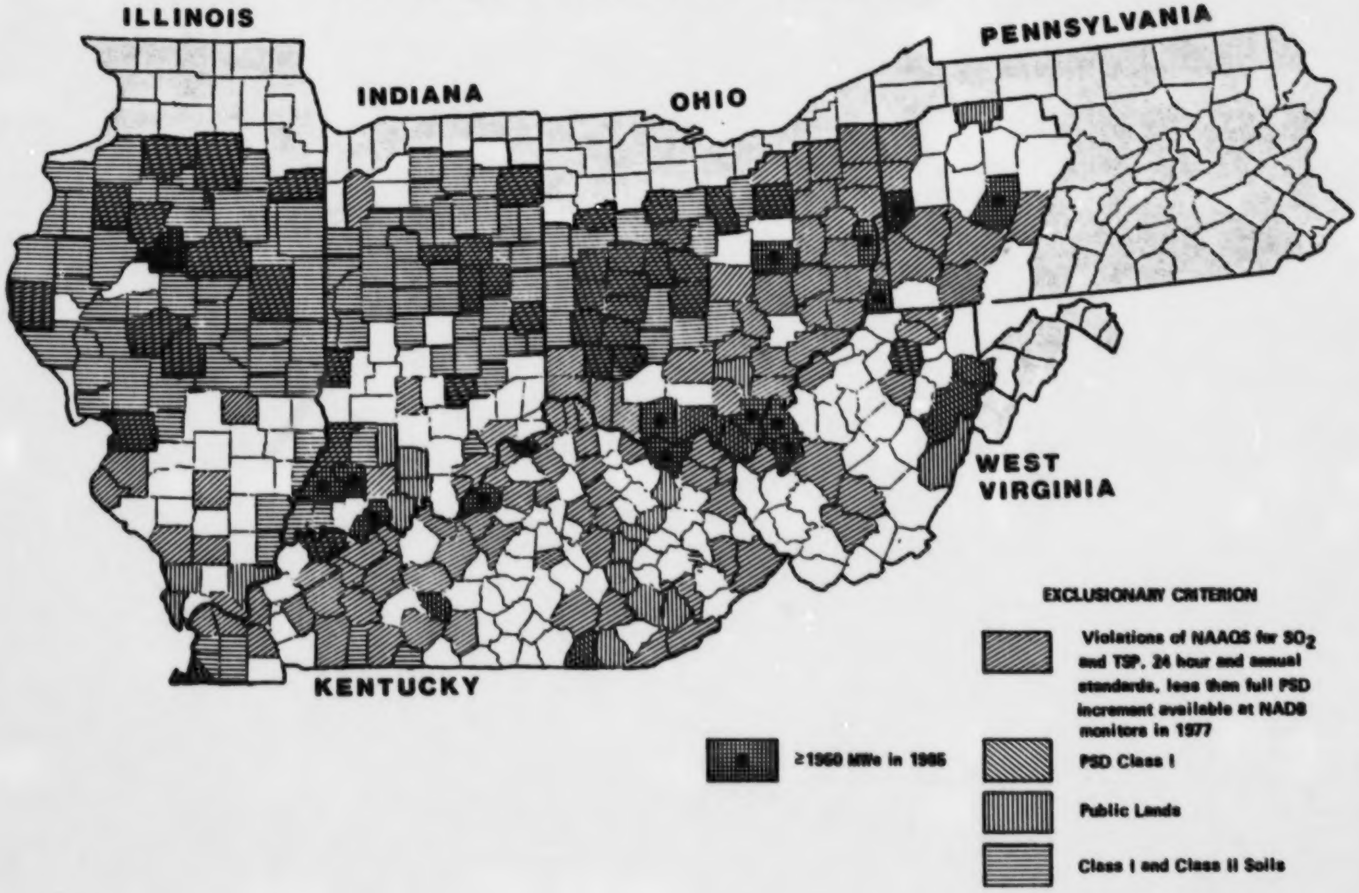
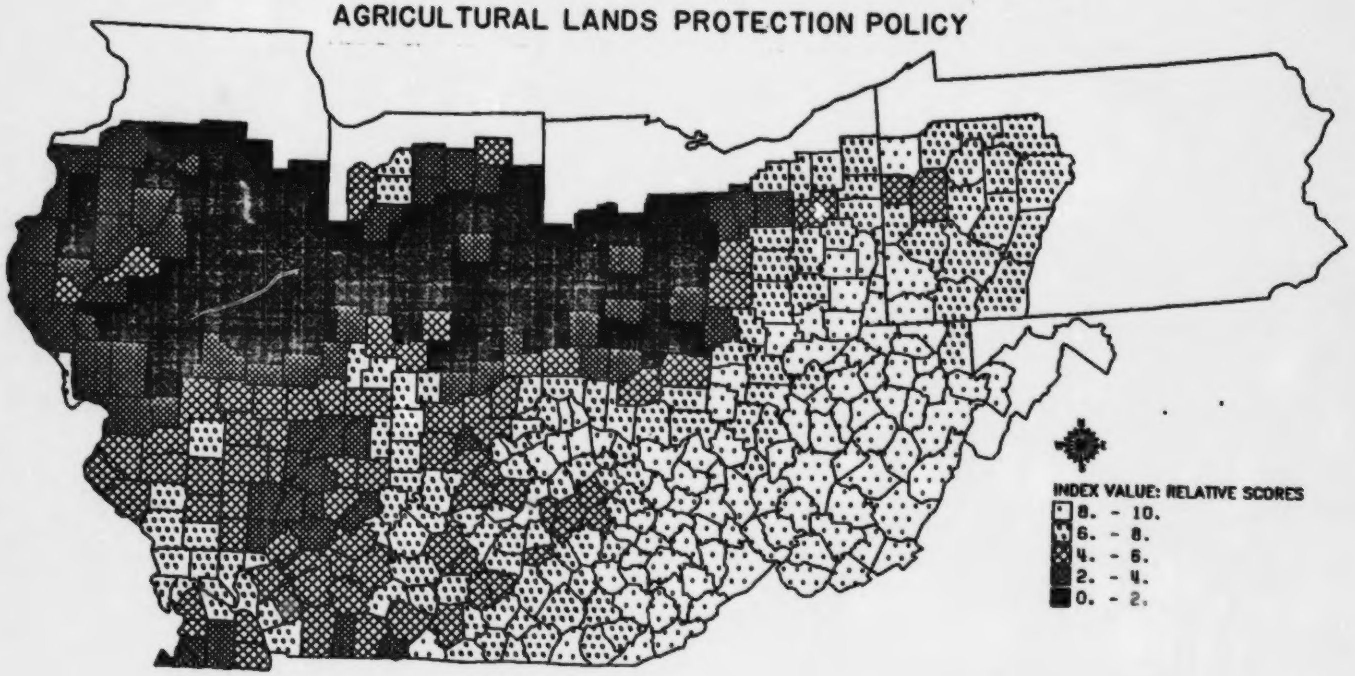

ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
WEST VIRGINIA
KENTUCKY
EXCLUSIONARY CRITERION
Violations of NAAQS for SO_2 and TSP, 24 hour and annual standards, less than full PSD increment available at NADB monitors in 1977
PSD Class I
Public Lands
Class I and Class II Soils
≥1960 MWe in 1985

Figure 47. **ECOLOGICAL SYSTEMS AND LAND USE COMPONENT**

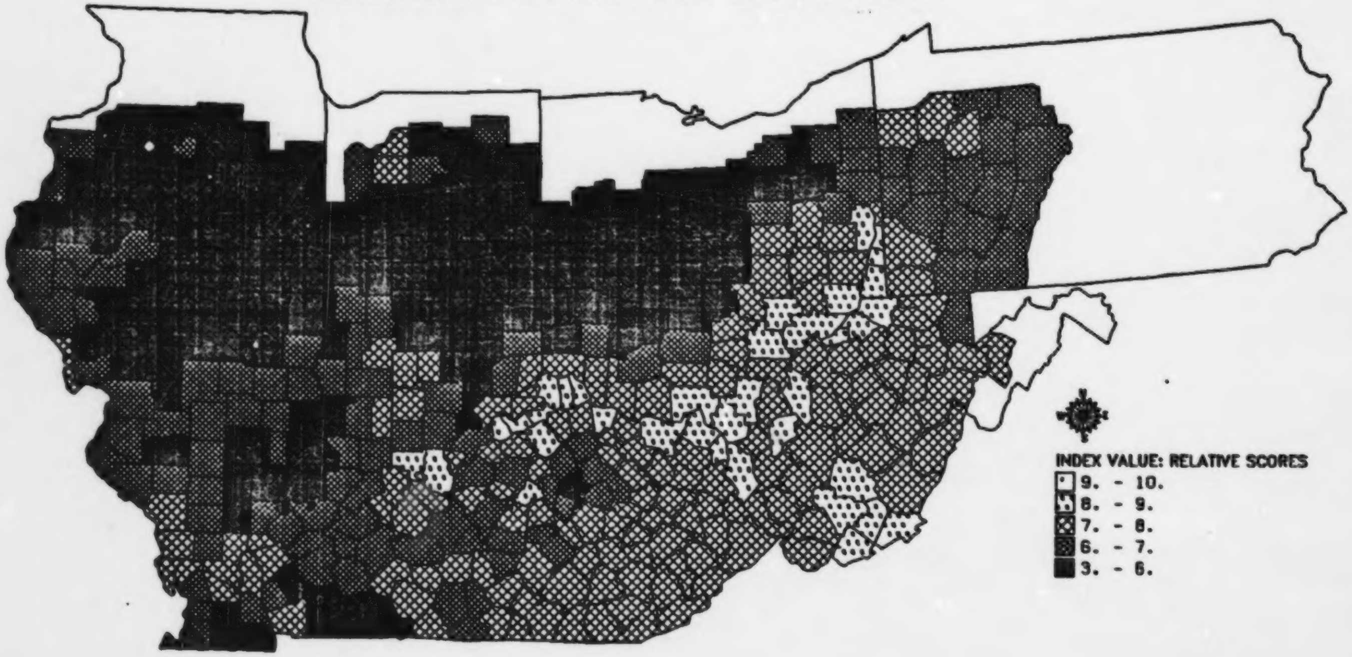
AGRICULTURAL LANDS PROTECTION POLICY



PREPARED FOR OHIO RIVER BASIN ENERGY STUDY
BY CAGIS/UICC, FEBRUARY, 1980

Figure 48. **SITE SUITABILITY INDEX**

AGRICULTURAL LANDS PROTECTION POLICY



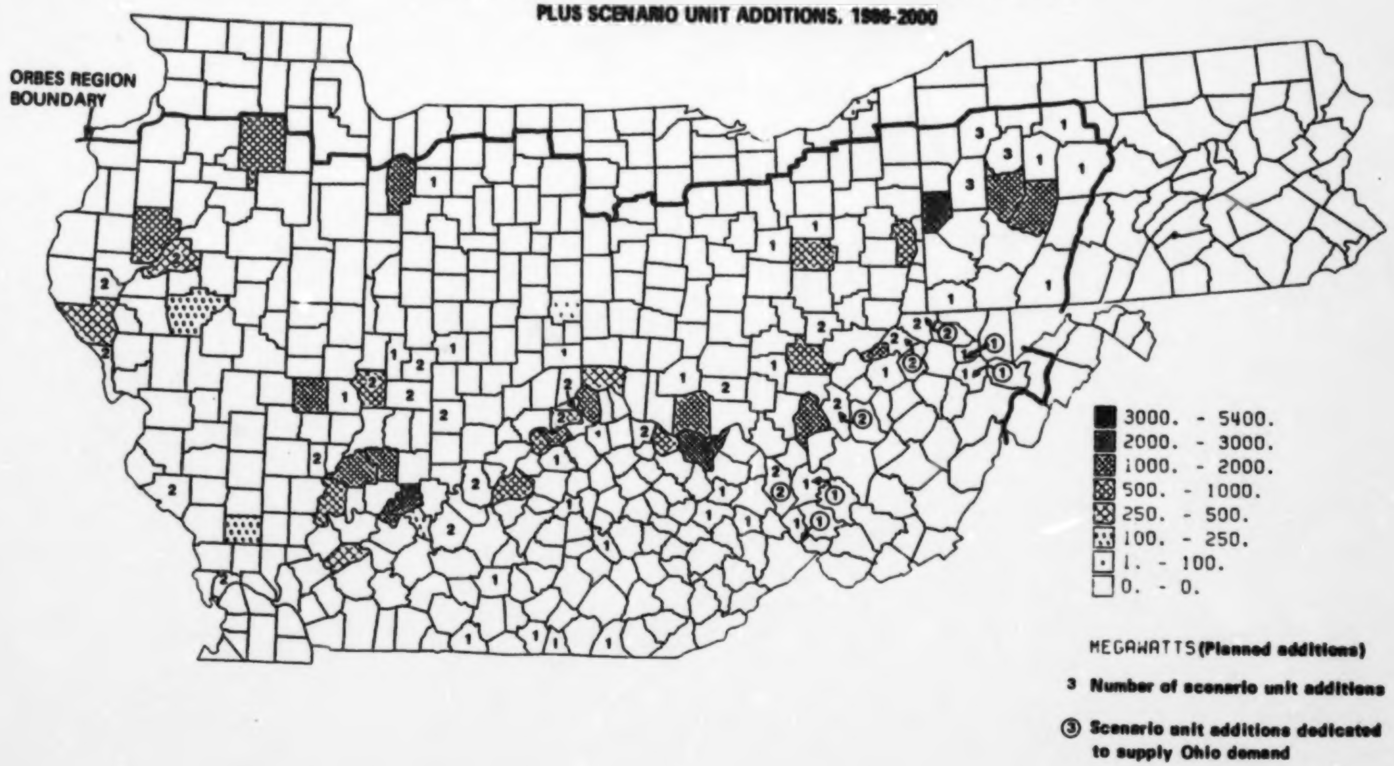
PREPARED FOR OHIO RIVER BASIN ENERGY STUDY
BY CAGIS/UICC, FEBRUARY, 1980

in counties along the Ohio River that have air quality problems. The siting pattern in Kentucky is also changed, as interior agricultural regions, such as the Bluegrass basin around Lexington, are less suitable as sites for capacity additions. The most significant change, however, is the need to locate the majority of the scenario units that are necessary to meet Ohio's demand for electricity in West Virginia. Relatively few Ohio counties are candidates for scenario unit additions because they do not meet threshold requirements for air quality and agricultural lands criteria. Consequently, Ohio's "excess" units are added to counties that are already designated as sites for capacity additions dedicated to serve West Virginia.

The regional siting pattern suggests that implementation of an agricultural lands protection policy relative to siting electricity generating units will involve tradeoffs among air quality, water availability, and land use and ecological systems impacts (Figure 49). Assuming that agricultural lands protection policies and strict air quality controls are at least compatible, candidate counties will be restricted to a band in the western part of the region between the areas of prime agricultural lands and the Ohio River main stem and in the eastern part of the region. The candidate counties are located in Kentucky and West Virginia. In the case of West Virginia (and perhaps Kentucky also), that state's role as an exporter of electricity generated by coal-fired plants might increase.

Figure 49

SCENARIO IC:
AGRICULTURAL LANDS PROTECTION, DISPERSED SITING
TOTAL PROPOSED COAL-FIRED GENERATING
CAPACITY ADDITIONS, 1976-85
PLUS SCENARIO UNIT ADDITIONS, 1986-2000


ORBES REGION BOUNDARY
3000. - 5400.
2000. - 3000.
1000. - 2000.
500. - 1000.
250. - 500.
100. - 250.
1. - 100.
0. - 0.
MEGAWATTS (Planned additions)
3 Number of scenario unit additions
③ Scenario unit additions dedicated to supply Ohio demand

FOOTNOTES

[1] The siting patterns for the scenarios that are analyzed in detail in the impact assessment are discussed in this section. The siting patterns and schedules of on-line dates for all scenarios are in: Fowler et al (1980).

[2] This is to be expected, as the ORBES siting model is designed to simulate, at large scale, utility siting under current conditions.

[3] Some rescheduling is necessary in order to accomodate the number of scenario unit additions that are required to meet the incremental demand for Scenario 7. Also, fewer existing and planned units are retired (a total of 15,473 MWe) because of the 45 year useful plant life assumption.

[4] Siting patterns for each of the scenarios that emphasizes coal-fired electricity generating units and base case environmental control policies have a number of sites (counties) in common. Scenarios that have more scenario unit additions than in Scenario 2 add counties that always have lower site suitability indices. Scenarios that have fewer additions are, in effect, smaller subsets of counties with higher suitability indices.

[5] Illinois Times, March 9-15, 1979, p. 3.

[6] Two siting patterns are developed for these and the agricultural lands protection scenarios. In Scenario 1a and 1c, 2600 MWe is the maximum coal-fired electrical generating capacity that can be sited in a county. This is consistent with the 'dispersed' siting policy of Scenario 1, and permits impact assessment under the changes in environmental controls only. In Scenario 1b and 1d, the maximum is increased to 5200 MWe. This allows generating unit additions to be 'concentrated' in candidate counties that are more suitable sites, and in which the utilities have sites that can accomodate capacity additions. The result in each case is to locate a larger number of scenario unit additions in the most suitable candidate counties in each state subregion. Fewer counties are involved and, in general, the distance between them is increased. Thus, the use of a policy of 'concentrated' siting to mitigate impacts can be evaluated. The siting patterns and schedules of on-line dates for each of these scenarios are in: Fowler et al (1980).

[7] This also implies that the county is the most relevant geographical area for air quality control decisions. The issue of separation distances is also relevant to the geographical definition of exclusionary criteria as well as site evaluation. Litigation involving IPALCO's Patriot plant in Switzerland County, Indiana, is a case in point. However, the definition of separation distances is not sufficiently precise for inclusion into the siting model. See: Garvey et al (1977).

well as site evaluation. Litigation involving IPALCO's Patriot plant in Switzerland County, Indiana, is a case in point. However, the definition of separation distances is not sufficiently precise for inclusion into the siting model. See: Garvey et al (1977).

[8] See: Appendix D.

[9] The 1800 acre Greene County site is being purchased by Illinois Power Company; Illinois Times, April 21-27, 1978. The Mid-America Interpool Network (MAIN) Regional Reliability Council, which includes the ORBES portion of Illinois, does not have a utility site inventory similar to that available from ECAR.

[10] The protection of agricultural land recently has become a major policy goal at national and state level. Agencies such as the U.S. Department of Agriculture and the USEPA (1977) have developed agricultural lands protection policies as part of their resource development and environmental protection activities. In the ORBES region, conflicts between farmland and energy development, which are described in general by Fletcher (1980), focus upon the Illinois, Indiana and Ohio state subregions (Randolph and Jones, forthcoming).

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APPENDICES

APPENDIX A

SITED CAPACITY ADDITIONS, 1976 THROUGH 2000

The following tables (A.1 through A.6) list sited capacity additions by state subdivisions of the ORBES region. The entries represent published electric utility company plans for capacity additions as of December 31, 1976. Nine separate pieces of information are given for each generating unit addition:

Column 1 UNIT ID = Unit Identification
Column 2 CO INDEX = Company Index
Column 3 NAME = Unit Name
Column 4 COUNTY = FIPS County Code
Column 5 MWE = Capacity In MWe
Column 6 STATUS = Unit Status
Column 7 DATE = On-line Date
Column 8 RETIRE = Retirement Date
Column 9 FUEL = Primary Fuel

A period (.) in a column indicates that no information was available for that entry. Further details concerning the interpretation of the coded data are available in:

> Steven D. Jansen, University of Illinois at Chicago Circle,
> "Electrical Generating Unit Inventory, 1976-1986: Illinois,
> Indiana, Kentucky, Ohio, Pennsylvania, and West Virgina,"
> Ohio River Basin Energy Study Phase II, Grant No. EPA R805590
> (Washington, D.C., November 1978).

In calculating the number of required scenario unit additions, it is assumed that these planned and sited capacity additions will be built as listed in the following tables. Only those generating unit additions for which the county site is known are used in the calculation of scenario unit additions. Units which have a period (.) in the column for county are unsited and are given in the tables only to convey as much information as possible about utility plans.

Table A.1. SITED CAPACITY ADDITIONS, 1976 THROUGH 2000: ILLINOIS

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
1	COEC	COLLINS	63	515	U	7804	.	F06
2	COEC	COLLINS	63	510	U	7710	.	F06
3	COEC	COLLINS	63	500	U	7704	.	F06
4	COEC	COLLINS	63	505	U	7810	.	F06
5	COEC	COLLINS	63	505	U	7904	.	F06
1	COEC	LASALLE COUNTY	99	1078	U	7909	.	UR
2	COEC	LASALLE COUNTY	99	1078	U	8009	.	UR
1	ILPC	CLINTON	39	950	U	8112	.	UR
2	ILPC	CLINTON	39	950	U	8406	.	UR
6	ILPC	HAVANA	125	450	U	7806	.	COL
4	SOIP	MARION	199	173	U	7806	.	COL
2	CEIL	DUCK CREEK	57	400	P	8201	.	COL
1	CEIP	NEWTON	79	617	P	7712	.	COL
2	CEIP	NEWTON	79	600	P	8104	.	COL
3	CEIP	NEWTON	79	600	P	8404	.	COL
P1	COEC	UNSITED	99	600	P	8501	.	UNK
P3	COEC	UNSITED	99	550	P	8504	.	COL
	ILPC	UNSITED	.	600	P	8606	.	COL
	ILPC	UNSITED	.	400	P	8406	.	OIL
5	SOIP	MARION	199	173	P	8600	.	COL
3	SPFI	DALLMAN	167	192	P	7806	.	COL
2	SPFI	FACTORY	167	50	P	8401	.	OIL
1	SPFI	PLANT 4-1	.	175	P	8601	.	COL
2	SPFI	REYNOLDS	167	50	P	8101	.	OIL
	SPFI	UNSITED	.	192	P	8606	.	COL
2	UNEC	VENICE	119	220	P	7905	.	F02
2	WEIL	PEARL STATION	149	400	P	8400	.	COL
1	WEIL	UNSITED	.	20	P	8106	.	COL
2	WEIL	UNSITED	.	20	P	8406	.	COL
3	CEIL	DUCK CREEK	57	500	P	8900	.	COL
4	CEIL	DUCK CREEK	57	600	P	9000	.	COL

Table A.2. SITED CAPACITY ADDITIONS, 1976 THROUGH 2000: INDIANA

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
1	INME	ROCKPORT	147	1300	U	8112	.	COL
2	INME	ROCKPORT	147	1300	U	8212	.	COL
3	INPL	PETERSBURG	125	532	U	7711	.	COL
4	INPL	PETERSBURG	125	532	U	8204	.	COL
15	NOIP	SCHAHFER, R. M.	73	556	U	7905	.	COL
3	PSIN	GIBSON	51	650	U	7804	.	BIT
4	PSIN	GIBSON	51	650	U	7904	.	BIT
1	PSIN	MARBLE HILL	77	1130	U	8201	.	UR
1	SOIG	BROWN, A. B.	129	265	U	7904	.	COL
1	HEDI	MEROM	153	490	P	8009	.	COL
2	HEDI	MEROM	153	490	P	8109	.	COL
1	INPL	PATRIOT	155	650	P	8504	.	COL
2	PSIN	MARBLE HILL	77	1130	P	8404	.	UR
13	RCMP	RENSSELAER	73	6	P	8200	.	OIL
13	RCMP	UNKNOWN	73	6	P	8206	.	FO2
3	RICI	WHITEWATER VALLEY	177	100	P	8507	.	COL
2	SOIG	BROWN, A. B.	129	265	P	8304	.	COL
3	SOIG	BROWN, A. B.	129	500	P	8701	.	COL
4	SOIG	BROWN, A. B.	129	500	P	9301	.	COL

Table A.3. SITED CAPACITY ADDITIONS, 1976 THROUGH 2000: KENTUCKY

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
2	KEUC	GHENT	41	550	T	7706	.	COL
2	CETV	LAUREL	125	61	U	7700	.	WAT
1	EAKR	SPURLOCK, H L	161	300	U	7706	.	COL
2	EAKR	SPURLOCK, H L	161	500	U	8103	.	COL
3	LOGE	MILL CREEK	111	425	U	7805	.	COL
4	LOGE	MILL CREEK	111	495	U	8006	.	COL
1	LOGE	TRIMBLE COUNTY	223	495	U	8306	.	COL
1	BIRI	GREEN	233	240	P	7912	.	COL
2	BIRI	GREEN	233	240	P	8004	.	COL
4	BIRI	COLEMAN	91	240	P	8400	.	COL
1	BIRI	STATION 4	.	500	P	8500	.	COL
1	CIGE	EAST BEND	15	600	P	8401	.	COL
2	CIGE	EAST BEND	15	600	P	8006	.	COL
	EAKR	UNSITED	.	650	P	8400	.	COL
1	KEPC	LEWIS COUNTY	135	1300	P	8312	.	COL
2	KEPC	LEWIS COUNTY	135	1300	P	8412	.	COL
3	KEUC	GHENT	41	550	P	8103	.	COL
4	KEUC	GHENT	41	550	P	8303	.	COL
1	KEUC	UNSITED - SITE A	.	650	P	8504	.	COL
2	KEUC	UNSITED-SITE A	.	650	P	8600	.	COL
2	LOGE	TRIMBLE COUNTY	223	495	P	8506	.	COL
	LOGE	UNSITED	111	65	P	8406	.	F02
	VEHP	CANNELTON	91	70	P	8000	.	WAT
3	CIGE	EAST BEND	15	800	P	8701	.	COL
3	LOGE	TRIMBLE COUNTY	223	675	I	9999	.	COL
4	LOGE	TRIMBLE COUNTY	223	675	I	9999	.	COL

Table A.4. SITED CAPACITY ADDITIONS, 1976 THROUGH 2000: OHIO

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
3	BUPI	CARDINAL	81	615	U	7709	.	COL
8	CIGE	MIAMI FORT	61	500	U	7803	.	COL
1	CIGE	W. H. ZIMMER	25	810	U	7907	.	UR
6	COSO	CONESVILLE	31	403	U	7801	.	COL
5	COSO	POSTON	9	403	U	8301	.	COL
6	COSO	POSTON	9	403	U	8501	.	COL
2	DAPO	KILLEN STATION	1	600	U	8201	.	COL
	COLU	COLUMBUS	49	90	P	8100	.	REF
1	DAPO	KILLEN STATION	1	600	P	8501	.	COL
1	OHPC	RACINE	105	40	P	7912	.	WAT
	VEHP	GREENUP	145	70	P	8000	.	WAT
2	CIGE	W. H. ZIMMER	25	810	I	9999	.	UR

Table A.5. SITED CAPACITY ADDITIONS, 1976 THROUGH 2000: PENNSYLVANIA

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
1	DULC	BEAVER VALLEY	7	85	A	7803	.	UR
2	DULC	BEAVER VALLEY	7	29	A	8404	.	UR
1	DULC	BEAVER VALLEY	7	800	U	7704	.	UR
2	DULC	BEAVER VALLEY	7	856	U	8205	.	UR
1	DULC	SHIPPINGPORT	7	60	U	7710	.	UR
3	PEEC	HOMER CITY	63	693	U	7712	.	COL
2	PEPC	MANSFIELD	7	917	U	7710	.	COL
3	PEPC	MANSFIELD	7	917	U	8010	.	COL
7	PEEC	SEWARD	63	800	P	8405	.	COL
1	WEPP	LOWER ARMSTRONG	5	630	P	8303	.	COL
2	WEPP	LOWER ARMSTRONG	5	630	P	8403	.	COL
3	WEPP	LOWER ARMSTRONG	5	630	P	8503	.	COL

Table A.6. SITED CAPACITY ADDITIONS, 1976 THROUGH 2000: WEST VIRGINIA

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
1	APPC	NEW HAVEN	53	1300	U	8012	.	COL
1	MOPC	PLEASANTS	73	626	U	7903	.	COL
2	MOPC	PLEASANTS	73	626	U	8003	.	COL
1	MOPC	DAVIS POWER PROJ.	93	250	P	8603	.	WAT
2	MOPC	DAVIS POWER PROJ.	93	250	P	8606	.	WAT
3	MOPC	DAVIS POWER PROJ.	93	250	P	8799	.	WAT
4	MOPC	DAVIS POWER PROJ.	93	250	P	8799	.	WAT

APPENDIX B

CAPACITY REMOVALS, 1976 THROUGH 2000

The following tables (B.1 through B.6) list capacity removals or retirements by state subdivisions of the ORBES region. Nine separate pieces of information are given for each generating unit removal:

Column 1 UNIT_ID = Unit Identification
Column 2 CO_INDEX = Company Index
Column 3 NAME = Unit Name
Column 4 COUNTY = FIPS County Code
Column 5 MWE = Capacity In MWe
Column 6 STATUS = Unit Status
Column 7 DATE = On-line Date
Column 8 RETIRE = Retirement Date
Column 9 FUEL = Primary Fuel

A period (.) in a column indicates that no information was available for that entry. Further details concerning the interpretation of the coded data are available in:

> Steven D. Jansen, University of Illinois at Chicago Circle, "Electrical Generating Unit Inventory, 1976-1986: Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia," Ohio River Basin Energy Study Phase II, Grant No. EPA R805590 (Washington, D.C., November 1978).

It is assumed that units with retirement dates earlier than the year 2000 will be retired by 2000. Units for which the on-line date and the retirement date are both unknown are also assumed to retire by 2000. All units that have on-line dates earlier than 1967 will be more than 35 years old in 2000 and are assumed to be retired by 2000. Although most hydroelectric (fuel is WAT) generating units fit into one of the above categories and are, therefore, listed in the following tables,they are not considered as retirements for calculating the number of scenario unit additions.

Table B.1. CAPACITY REMOVALS, 1976 THROUGH 2000: ILLINOIS

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
1	BETY	BETHANY	139	1	S	6000	.	UNK
2	BETY	BETHANY	139	1	S	5200	.	UNK
1	BREE	BREESE	27	1	S	4800	.	OIL
2	BREE	BREESE	27	1	S	5300	.	OIL
3	BREE	BREESE	27	2	S	6000	.	OIL
1	BUSH	BUSHNELL	109	1	S	4000	.	OIL
2	BUSH	BUSHNELL	109	1	S	4000	.	OIL
3	BUSH	BUSHNELL	109	2	S	6500	.	OIL
4	BUSH	BUSHNELL	109	2	S	6500	.	OIL
5	BUSH	BUSHNELL	109	1	S	4800	.	OIL
7	BUSH	BUSHNELL	109	1	S	5600	.	OIL
5	CALW	CARMI	193	1	S	4500	.	OIL
6	CALW	CARMI	193	1	S	3900	.	OIL
7	CALW	CARMI	193	1	S	4800	.	OIL
8	CALW	CARMI	193	1	S	5100	.	OIL
9	CALW	CARMI	193	2	S	5800	.	OIL
10	CALW	CARMI	193	2	S	5800	.	OIL
11	CALW	CARMI	193	3	S	6300	.	OIL
2	CARL	CARLYLE	27	1	S	3900	.	COL
3	CARL	CARLYLE	27	3	S	4900	.	COL
4	CARL	CARLYLE	27	1	S	5900	.	OIL
5	CARL	CARLYLE	27	1	S	5900	.	OIL
6	CARL	CARLYLE	27	1	S	5900	.	OIL
7	CARL	CARLYLE	27	2	S	6400	.	OIL
1	CEIL	E D EDWARDS	143	136	S	6000	.	COL
3	CEIL	R S WALLACE	179	25	S	3900	.	COL
4	CEIL	R S WALLACE	179	40	S	4100	.	COL
5	CEIL	R S WALLACE	179	40	S	4900	.	COL
6	CEIL	R S WALLACE	179	86	S	5200	.	COL
7	CEIL	R S WALLACE	179	114	S	5800	.	COL
1	CEIP	COFFEEN	135	389	S	6512	.	COL
3	CEIP	GRAND TOWER	77	81	S	5103	.	COL
4	CEIP	GRAND TOWER	77	114	S	5804	.	COL
1	CEIP	HUTSONVILLE	33	25	S	4005	8510	F02
2	CEIP	HUTSONVILLE	33	25	S	4109	8510	F02
3	CEIP	HUTSONVILLE	33	75	S	5302	.	COL
4	CEIP	HUTSONVILLE	33	75	S	5407	.	COL
1	CEIP	MEREDOSIA	137	58	S	4806	.	COL
2	CEIP	MEREDOSIA	137	58	S	4901	.	COL
3	CEIP	MEREDOSIA	137	239	S	6007	.	COL
1	COEC	DRESDEN	63	209	S	6000	.	UR
1	ELNE	JOPPA STEAM	127	183	S	5300	.	COL
2	ELNE	JOPPA STEAM	127	183	S	5300	.	COL
3	ELNE	JOPPA STEAM	127	183	S	5400	.	COL

(continued)

Table B.1. (continued)

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
4	ELNE	JOPPA STEAM	127	183	S	5400	.	COL
5	ELNE	JOPPA STEAM	127	183	S	5500	.	COL
6	ELNE	JOPPA STEAM	127	183	S	5500	.	COL
2	FACI	FARMER CITY	39	1	S	6300	.	OIL
3	FACI	FARMER CITY	39	1	S	4500	.	OIL
4	FACI	FARMER CITY	39	1	S	5000	.	OIL
1	FMLP	FAIRFIELD	191	2	S	4000	.	COL
2	FMLP	FAIRFIELD	191	2	S	4200	.	COL
3	FMLP	FAIRFIELD	191	4	S	4900	.	COL
4	FMLP	FAIRFIELD	191	5	S	5600	.	COL
1	FREE	FREEBURG	163	1	S	4800	.	OIL
2	FREE	FREEBURG	163	1	S	4800	.	OIL
3	FREE	FREEBURG	163	1	S	5300	.	OIL
4	FREE	FREEBURG	163	1	S	5900	.	OIL
4	GEMU	GENESEO	73	2	S	5700	.	OIL
5	GEMU	GENESEO	73	1	S	4900	.	OIL
6	GEMU	GENESEO	73	1	S	4700	.	OIL
7	GEMU	GENESEO	73	3	S	6100	.	OIL
1	HIGH	HIGHLAND	119	2	S	3600	.	COL
2	HIGH	HIGHLAND	119	2	S	4800	.	COL
3	HIGH	HIGHLAND	119	3	S	4700	.	COL
4	HIGH	HIGHLAND	119	6	S	6100	.	COL
1	ILPC	BLOOMINGTON	113	1	S	3200	.	OIL
2	ILPC	BLOOMINGTON	113	1	S	3200	.	OIL
5	ILPC	BLOOMINGTON	113	2	S	4900	.	OIL
6	ILPC	BLOOMINGTON	113	2	S	6000	.	OIL
1	ILPC	HAVANA	125	52	S	4700	.	OIL
2	ILPC	HAVANA	125	52	S	4700	.	OIL
3	ILPC	HAVANA	125	52	S	4800	.	OIL
4	ILPC	HAVANA	125	52	S	5000	.	OIL
5	ILPC	HAVANA	125	52	S	5000	.	OIL
1	ILPC	HENNEPIN	155	75	S	5300	.	COL
2	ILPC	HENNEPIN	155	106	S	5900	.	COL
3	ILPC	HENNEPIN	155	125	S	5900	.	COL
5	ILPC	JACKSONVILLE	137	2	S	4900	.	OIL
6	ILPC	JACKSONVILLE	137	3	S	5200	.	OIL
1-7	ILPC	MARSEILLES	99	2	S	.	.	WAT
1	ILPC	VANDALIA	51	1	S	4800	.	OIL
2	ILPC	VANDALIA	51	1	S	4800	.	OIL
1	ILPC	VERMILION	183	75	S	5500	.	COL
2	ILPC	VERMILION	183	107	S	5600	.	COL
1	ILPC	WOOD RIVER	119	49	S	4900	.	OIL
2	ILPC	WOOD RIVER	119	50	S	4900	.	OIL
3	ILPC	WOOD RIVER	119	51	S	5000	.	OIL

(continued)

Table B.1. (continued)

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
4	ILPC	WOOD RIVER	119	103	S	5400	.	COL
5	ILPC	WOOD RIVER	119	397	S	6400	.	COL
	LIOF	OTTAWA	99	32	S	.	.	UNK
1	MAIL	MARSHALL	23	1	S	4800	.	OIL
2	MAIL	MARSHALL	23	1	S	4800	.	OIL
3	MAIL	MARSHALL	23	1	S	5300	.	OIL
4	MAIL	MARSHALL	23	3	S	6200	.	OIL
GT1	MCLE	MC LEANSBORO	65	1	S	5800	.	GAS
IC1	MCLE	MC LEANSBORO	65	1	S	4900	.	OIL
IC2	MCLE	MC LEANSBORO	65	1	S	5000	.	OIL
IC3	MCLE	MC LEANSBORO	65	1	S	5200	.	OIL
IC4	MCLE	MC LEANSBORO	65	2	S	6300	.	OIL
IC1	MCPD	MASCOUTAH	163	1	S	5100	.	OIL
IC2	MCPD	MASCOUTAH	163	1	S	5100	.	OIL
IC3	MCPD	MASCOUTAH	163	1	S	5800	.	OIL
1	MCPU	MT CARMEL	185	2	S	4100	.	COL
2	MCPU	MT CARMEL	185	4	S	4900	.	COL
3	MCPU	MT CARMEL	185	8	S	5200	.	COL
4	MCPU	MT CARMEL	185	8	S	5700	.	COL
1	NOCH	DAYTON	99	2	S	2500	.	WAT
2	NOCH	DAYTON	99	1	S	2500	.	WAT
3	NOCH	DAYTON	99	1	S	2500	.	WAT
1	PERU	PERU	99	1	S	3600	.	OIL
2	PERU	PERU	99	3	S	3800	.	COL
3	PERU	PERU	99	4	S	5000	.	COL
4	PERU	PERU	99	8	S	6000	.	COL
1	PMIL	PRINCETON	11	3	S	5300	.	OIL
2	PMIL	PRINCETON	11	3	S	5800	.	OIL
3	PMIL	PRINCETON	11	4	S	6500	.	OIL
4	PMIL	PRINCETON	11	4	S	6500	.	OIL
2	REBU	RED BUD	157	1	S	5900	.	OIL
3	REBU	RED BUD	157	2	S	6500	.	OIL
5	REBU	RED BUD	157	1	S	4800	.	OIL
6	REBU	RED BUD	157	1	S	5300	.	OIL
4	ROOD	ROODHOUSE	61	1	S	5700	.	OIL
5	ROOD	ROODHOUSE	61	1	S	6400	.	OIL
1-3	ROOD	ROODHOUSE	61	1	S	5000	.	OIL
1	RVLP	RANTOUL	19	1	S	5100	.	OIL
2	RVLP	RANTOUL	19	1	S	5100	.	OIL
3	RVLP	RANTOUL	19	1	S	5300	.	OIL
4	RVLP	RANTOUL	19	1	S	5400	.	OIL
5	RVLP	RANTOUL	19	1	S	6400	.	OIL
6	RVLP	RANTOUL	19	1	S	6400	.	OIL
8	RVLP	RANTOUL	19	4	S	6400	.	OIL

(continued)

Table B.1. (continued)

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
2	WCLP	WATERLOO	133	1	S	5400	.	OIL
3	WCLP	WATERLOO	133	1	S	4600	.	OIL
4	WCLP	WATERLOO	133	2	S	6400	.	OIL
5	WCLP	WATERLOO	133	1	S	5000	.	OIL
6	WCLP	WATERLOO	133	1	S	5000	.	OIL
7	WCLP	WATERLOO	133	2	S	5800	.	OIL
1	WEIL	PITTSFIELD	149	1	S	4900	.	OIL
2	WEIL	PITTSFIELD	149	1	S	4900	.	OIL
3	WEIL	PITTSFIELD	149	1	S	4900	.	OIL
4	WEIL	PITTSFIELD	149	3	S	5500	.	OIL
5	WEIL	PITTSFIELD	149	3	S	5500	.	OIL
1	WEIL	WINCHESTER	171	1	S	3800	.	OIL
2	WEIL	WINCHESTER	171	1	S	3800	.	OIL
3	WEIL	WINCHESTER	171	1	S	3800	.	OIL
4	WEIL	WINCHESTER	171	1	S	4700	.	OIL
5	WEIL	WINCHESTER	171	1	S	4700	.	OIL
1	SOIP	MARION	199	33	S	6306	.	COL
2	SOIP	MARION	199	33	S	6308	.	COL
3	SOIP	MARION	199	33	S	6309	.	COL
1	SPFI	LAKESIDE	167	10	S	3600	8101	COL
2	SPFI	LAKESIDE	167	15	S	3900	8101	COL
3	SPFI	LAKESIDE	167	15	S	4000	.	COL
4	SPFI	LAKESIDE	167	20	S	4900	.	COL
5	SPFI	LAKESIDE	167	20	S	5300	.	COL
6	SPFI	LAKESIDE	167	38	S	6000	.	COL
7	SPFI	LAKESIDE	167	38	S	6500	.	COL
2	SUIL	SULLIVAN	139	2	S	6100	.	OIL
3	SUIL	SULLIVAN	139	2	S	5600	.	OIL
4	SUIL	SULLIVAN	139	1	S	5100	.	OIL
5	SUIL	SULLIVAN	139	1	S	4800	.	OIL
6	SUIL	SULLIVAN	139	1	S	4600	.	OIL
7	SUIL	SULLIVAN	139	1	S	3900	.	OIL
8	SUIL	SULLIVAN	139	1	S	3400	.	OIL
1	UNEC	VENICE NO. 2	119	40	S	4200	.	OIL
2	UNEC	VENICE NO. 2	119	40	S	4200	.	OIL
3	UNEC	VENICE NO. 2	119	98	S	4300	.	OIL
4	UNEC	VENICE NO. 2	119	98	S	4800	.	OIL
5	UNEC	VENICE NO. 2	119	98	S	5000	.	COL
6	UNEC	VENICE NO. 2	119	100	S	5000	.	COL
1	UNIL	ABBOTT	19	3	S	4000	.	OIL
2	UNIL	ABBOTT	19	3	S	4000	.	OIL
3	UNIL	ABBOTT	19	3	S	4800	.	OIL
4	UNIL	ABBOTT	19	3	S	5100	.	OIL
5	UNIL	ABBOTT	19	3	S	5500	.	OIL
6	UNIL	ABBOTT	19	8	S	5900	.	OIL
7	UNIL	ABBOTT	19	8	S	6200	.	OIL

Table B.2. CAPACITY REMOVALS, 1976 THROUGH 2000: INDIANA

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
1	ALCO	WARRICK	173	136	S	6000	.	COL
2	ALCO	WARRICK	173	136	S	6000	.	COL
3	ALCO	WARRICK	173	136	S	6000	.	COL
1	BLUF	BLUFFTON	179	1	S	4700	.	OIL
2	BLUF	BLUFFTON	179	1	S	4700	.	OIL
3	BLUF	BLUFFTON	179	3	S	5200	.	OIL
4	BLUF	BLUFFTON	179	3	S	5200	.	OIL
4	CRAW	CRAWFORDSVILLE	107	12	S	5500	8699	COL
5	CRAW	CRAWFORDSVILLE	107	13	S	6500	.	COL
1	FOWA	SAINT JOE DAM	3	1	S	2800	.	WAT
1	FRAF	FRANKFORT	23	6	S	4199	.	COL
2	FRAF	FRANKFORT	23	10	S	5299	.	COL
3	FRAF	FRANKFORT	23	17	S	6299	.	COL
	ICIU	CHARLESTOWN	19	55	S	.	.	UNK
1	INKE	CLIFTY CREEK	77	225	S	5502	.	COL
2	INKE	CLIFTY CREEK	77	225	S	5505	.	COL
3	INKE	CLIFTY CREEK	77	225	S	5507	.	COL
4	INKE	CLIFTY CREEK	77	225	S	5510	.	COL
5	INKE	CLIFTY CREEK	77	225	S	5511	.	COL
6	INKE	CLIFTY CREEK	77	225	S	5603	.	COL
1	INME	BREED	153	496	S	6000	.	COL
1	INME	TANNERS CREEK	29	153	S	5100	.	COL
2	INME	TANNERS CREEK	29	153	S	5200	.	COL
3	INME	TANNERS CREEK	29	215	S	5400	.	COL
4	INME	TANNERS CREEK	29	580	S	6400	.	COL
3	INPL	PERRY K	97	15	S	2300	.	COL
4	INPL	PERRY K	97	15	S	2400	.	COL
5	INPL	PERRY K	97	13	S	3800	.	COL
6	INPL	PERRY K	97	5	S	3800	.	COL
1	INPL	PRITCHARD, H T	109	46	S	4900	.	FO2
2	INPL	PRITCHARD, H T	109	46	S	5000	.	FO2
3	INPL	PRITCHARD, H T	109	50	S	5100	.	COL
4	INPL	PRITCHARD, H T	109	69	S	5300	.	COL
5	INPL	PRITCHARD, H T	109	69	S	5300	.	COL
6	INPL	PRITCHARD, H T	109	114	S	5600	.	COL
1	INPL	STOUT, ELMER W	97	37	S	3100	.	FO2
2	INPL	STOUT, ELMER W	97	37	S	3100	.	FO2
3	INPL	STOUT, ELMER W	97	38	S	4100	.	FO2
4	INPL	STOUT, ELMER W	97	43	S	4700	.	FO2
5	INPL	STOUT, ELMER W	97	114	S	5800	.	COL
6	INPL	STOUT, ELMER W	97	114	S	6100	.	COL
	INSR	HOOSIER	125	234	S	.	.	COL
2	LOSP	LOGANSPORT	17	6	S	2900	.	COL
3	LOSP	LOGANSPORT	17	8	S	3900	.	COL

(continued)

Table B.2. (continued)

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
4	LOSP	LOGANSPORT	17	18	S	5800	.	COL
5	LOSP	LOGANSPORT	17	25	S	6400	.	COL
1	NOIP	NORWAY	181	2	S	2305	.	WAT
2	NOIP	NORWAY	181	2	S	2305	.	WAT
3	NOIP	NORWAY	181	2	S	2305	.	WAT
4	NOIP	NORWAY	181	1	S	2305	.	WAT
1	NOIP	OAKDALE	15	4	S	2511	.	WAT
2	NOIP	OAKDALE	15	3	S	2511	.	WAT
3	NOIP	OAKDALE	15	4	S	2511	.	WAT
1	PERI	PERU	103	10	S	5000	.	COL
2	PERI	PERU	103	5	S	3300	.	COL
3	PERI	PERU	103	25	S	5900	.	COL
6	PSIN	EDWARDSPORT	83	35	S	4400	8501	F02
7	PSIN	EDWARDSPORT	83	40	S	4900	8501	BIT
8	PSIN	EDWARDSPORT	83	69	S	5100	8501	BIT
66	PSIN	EDWARDSPORT	83	3	S	4400	.	F02
1	PSIN	GALLAGHER, R	43	150	S	5900	.	BIT
2	PSIN	GALLAGHER, R	43	150	S	5800	.	BIT
3	PSIN	GALLAGHER, R	43	150	S	6000	.	BIT
4	PSIN	GALLAGHER, R	43	150	S	6100	.	BIT
1	PSIN	NOBLESVILLE	57	50	S	5000	8501	BIT
2	PSIN	NOBLESVILLE	57	50	S	5000	8501	BIT
1	PSIN	WABASH RIVER	167	113	S	5300	.	BIT
2	PSIN	WABASH RIVER	167	113	S	5300	.	BIT
3	PSIN	WABASH RIVER	167	113	S	5400	.	BIT
4	PSIN	WABASH RIVER	167	113	S	5400	.	BIT
5	PSIN	WABASH RIVER	167	125	S	5600	.	BIT
4	RCMP	RENSSELAER	73	1	S	4099	8212	F02
5	RCMP	RENSSELAER	73	2	S	5099	.	F02
6	RCMP	RENSSELAER	73	3	S	5799	.	F02
7	RCMP	RENSSELAER	73	3	S	6499	.	F02
1	RICI	WHITEWATER VALLEY	177	33	S	5500	.	COL
1	SOIG	CULLEY	173	50	S	5500	.	COL
1	SOIG	NORTHEAST	163	11	S	6300	.	GAS
2	SOIG	NORTHEAST	163	12	S	6400	.	GAS
1	SOIG	OHIO RIVER	163	8	S	2900	.	F02
2	SOIG	OHIO RIVER	163	13	S	2900	.	F02
3	SOIG	OHIO RIVER	163	13	S	3600	.	F02
4	SOIG	OHIO RIVER	163	20	S	3800	.	F02
5	SOIG	OHIO RIVER	163	23	S	4500	.	F02
6	SOIG	OHIO RIVER	163	23	S	4900	.	F02
7	SOIG	OHIO RIVER	163	23	S	5100	.	F02
1	WCIN	WASHINGTON	27	5	S	4700	.	COL
2	WCIN	WASHINGTON	27	5	S	5700	.	COL
3	WCIN	WASHINGTON	27	3	S	3800	.	COL
4	WCIN	WASHINGTON	27	5	S	5700	.	COL
1	RICI	JOHNSON STREET	177	15	M	3400	.	COL
4	RICI	JOHNSON STREET	177	15	M	4800	.	COL

Table B.3. CAPACITY REMOVALS, 1976 THROUGH 2000: KENTUCKY

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
1	CETV	WOLF CREEK	207	45	S	5100	.	WAT
2	CETV	WOLF CREEK	207	45	S	5100	.	WAT
3	CETV	WOLF CREEK	207	45	S	5100	.	WAT
4	CETV	WOLF CREEK	207	45	S	5200	.	WAT
5	CETV	WOLF CREEK	207	45	S	5200	.	WAT
6	CETV	WOLF CREEK	207	45	S	5200	.	WAT
1	EAKR	COOPER	199	121	S	6502	.	COL
1	EAKR	DALE	49	22	S	5412	.	COL
2	EAKR	DALE	49	22	S	5412	.	COL
3	EAKR	DALE	49	66	S	5708	.	COL
4	EAKR	DALE	49	66	S	6008	.	COL
1	HEND	POWER STATION ONE	101	1	S	4800	.	FO2
2	HEND	POWER STATION ONE	101	1	S	4800	.	FO2
3	HEND	POWER STATION ONE	101	5	S	5100	.	COL
4	HEND	POWER STATION ONE	101	5	S	5100	.	COL
5	HEND	POWER STATION ONE	101	19	S	5600	.	COL
1	HEND	POWER STATION TWO	233	148	S	.	.	COL
2	HEND	POWER STATION TWO	233	148	S	.	.	COL
1	KEPC	BIG SANDY	127	281	S	6301	.	COL
1	KEUC	BROWN, E W	167	114	S	5705	9200	COL
2	KEUC	BROWN, E W	167	180	S	6306	9800	COL
1	KEUC	DIX DAM	79	8	S	2599	.	WAT
2	KEUC	DIX DAM	79	8	S	2599	.	WAT
3	KEUC	DIX DAM	79	8	S	2599	.	WAT
1	KEUC	GREEN RIVER	177	32	S	5003	8500	COL
2	KEUC	GREEN RIVER	177	32	S	5001	8500	COL
3	KEUC	GREEN RIVER	177	75	S	5404	8900	COL
4	KEUC	GREEN RIVER	177	114	S	5907	9400	COL
1	KEUC	LOCK #7	167	1	S	2799	.	WAT
2	KEUC	LOCK #7	167	1	S	2799	.	WAT
3	KEUC	LOCK #7	167	1	S	2799	.	WAT
3	KEUC	PINEVILLE	13	35	S	5107	8600	COL
1	KEUC	TYRONE	239	31	S	4710	8200	FO2
2	KEUC	TYRONE	239	31	S	4806	8300	FO2
3	KEUC	TYRONE	239	75	S	5307	8800	COL
1	LOGE	CANE RUN	111	113	S	5400	8506	COL
2	LOGE	CANE RUN	111	113	S	5600	8606	COL
3	LOGE	CANE RUN	111	147	S	5800	8806	COL
4	LOGE	CANE RUN	111	163	S	6200	.	COL
1	LOGE	OHIO FALLS	111	10	S	2700	.	WAT
2	LOGE	OHIO FALLS	111	10	S	2700	.	WAT
3	LOGE	OHIO FALLS	111	10	S	2700	.	WAT
4	LOGE	OHIO FALLS	111	10	S	2700	.	WAT
5	LOGE	OHIO FALLS	111	10	S	2700	.	WAT

(continued)

Table B.3. (continued)

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
6	LOGE	OHIO FALLS	111	10	S	2700	.	WAT
7	LOGE	OHIO FALLS	111	10	S	2700	.	WAT
8	LOGE	OHIO FALLS	111	10	S	2700	.	WAT
1	LOGE	PADDY'S RUN	111	25	S	4200	7906	COL
2	LOGE	PADDY'S RUN	111	25	S	4200	7906	COL
3	LOGE	PADDY'S RUN	111	69	S	4700	8106	COL
4	LOGE	PADDY'S RUN	111	45	S	4900	8106	COL
5	LOGE	PADDY'S RUN	111	75	S	5000	8306	COL
6	LOGE	PADDY'S RUN	111	75	S	5200	8406	COL
7	LOGE	WATERSIDE	111	20	S	6400	.	GAS
8	LOGE	WATERSIDE	111	25	S	6400	.	GAS
1	OWEN	ELMER SMITH	59	149	S	6300	.	COL
1	OWEN	OWENSBORO	59	7	S	3900	7801	COL
2	OWEN	OWENSBORO	59	8	S	3900	7801	COL
4	OWEN	OWENSBORO	59	35	S	5400	8001	COL
1	TEVA	KENTUCKY	157	37	S	4500	.	WAT
2	TEVA	KENTUCKY	157	32	S	4400	.	WAT
3	TEVA	KENTUCKY	157	32	S	4400	.	WAT
4	TEVA	KENTUCKY	157	32	S	4500	.	WAT
5	TEVA	KENTUCKY	157	37	S	4800	.	WAT
1	TEVA	PARADISE	177	704	S	6311	.	COL
2	TEVA	PARADISE	177	704	S	6305	.	COL
1	TEVA	SHAWNEE	145	175	S	5304	.	COL
2	TEVA	SHAWNEE	145	175	S	5306	.	COL
3	TEVA	SHAWNEE	145	175	S	5310	.	COL
4	TEVA	SHAWNEE	145	175	S	5401	.	COL
5	TEVA	SHAWNEE	145	175	S	5410	.	COL
6	TEVA	SHAWNEE	145	175	S	5411	.	COL
7	TEVA	SHAWNEE	145	175	S	5412	.	COL
8	TEVA	SHAWNEE	145	175	S	5503	.	COL
9	TEVA	SHAWNEE	145	175	S	5507	.	COL
10	TEVA	SHAWNEE	145	175	S	5706	.	COL

Table B.4. CAPACITY REMOVALS, 1976 THROUGH 2000: OHIO

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
1	ARCA	ARCANUM	37	1	S	5100	.	OIL
2	ARCA	ARCANUM	37	1	S	4600	.	OIL
1	CIGE	DICK'S CREEK	17	120	S	6500	.	KER
3	CIGE	MIAMI FORT	61	65	S	3800	8001	F02
4	CIGE	MIAMI FORT	61	65	S	4200	8001	F02
5	CIGE	MIAMI FORT	61	100	S	4900	.	COL
6	CIGE	MIAMI FORT	61	163	S	6000	.	COL
1	CIGE	WALTER C BECKJORD	25	115	S	5200	.	COL
2	CIGE	WALTER C BECKJORD	25	113	S	5300	.	COL
3	CIGE	WALTER C BECKJORD	25	125	S	5400	.	COL
4	CIGE	WALTER C BECKJORD	25	163	S	5800	.	COL
5	CIGE	WALTER C BECKJORD	25	245	S	6200	.	COL
1	COLU	COLUMBUS	49	8	S	.	7711	UNK
3	COLU	COLUMBUS	49	8	S	.	7711	UNK
6	COLU	COLUMBUS	49	13	S	.	7711	COL
7	COLU	COLUMBUS	49	13	S	.	7711	UNK
8	COLU	COLUMBUS	49	13	S	.	8011	GAS
1	COSO	CONESVILLE	31	125	S	5999	.	COL
2	COSO	CONESVILLE	31	125	S	5799	.	COL
3	COSO	CONESVILLE	31	125	S	6299	.	COL
3	COSO	PICWAY	129	30	S	4399	8010	COL
4	COSO	PICWAY	129	30	S	4999	8010	COL
5	COSO	PICWAY	129	85	S	5599	.	COL
1	COSO	POSTON	9	40	S	4999	.	COL
2	COSO	POSTON	9	40	S	5099	.	COL
3	COSO	POSTON	9	60	S	5299	.	COL
4	COSO	POSTON	9	60	S	5499	.	COL
1	DAPO	FRANK M TAIT	113	30	S	4501	.	F02
2	DAPO	FRANK M TAIT	113	30	S	4204	.	F02
3	DAPO	FRANK M TAIT	113	35	S	5112	.	F02
4	DAPO	FRANK M TAIT	113	147	S	5806	.	COL
5	DAPO	FRANK M TAIT	113	147	S	5905	.	COL
7	DAPO	FRANK M TAIT	113	30	S	3710	.	F02
8	DAPO	FRANK M TAIT	113	30	S	4007	.	F02
1	DAPO	HUTCHINGS	113	69	S	4807	.	COL
2	DAPO	HUTCHINGS	113	69	S	4903	.	COL
3	DAPO	HUTCHINGS	113	69	S	5012	.	COL
4	DAPO	HUTCHINGS	113	69	S	5102	.	COL
5	DAPO	HUTCHINGS	113	69	S	5211	.	COL
6	DAPO	HUTCHINGS	113	69	S	5308	.	COL
	DOVE	DOVER	157	33	S	.	.	COL
	FITR	AKRON	153	58	S	.	.	UNK
	GOTR	AKRON	153	65	S	.	.	UNK
9	HAMI	HAMILTON	17	50	S	2900	.	COL

(continued)

Table B.4. (continued)

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
4	HAMI	HAMILTON	17	9	S	3800	.	COL
5	HAMI	HAMILTON	17	10	S	5400	.	COL
7	HAMI	HAMILTON	17	22	S	6000	.	OIL
GT1	HAMI	HAMILTON	17	11	S	6400	.	OIL
1	HAMI	HAMILTON HYDRO	17	1	S	1900	.	WAT
1	LEOH	LEBANON	165	1	S	4000	.	OIL
3	LEOH	LEBANON	165	1	S	4900	.	OIL
4	LEOH	LEBANON	165	1	S	5000	.	OIL
5	LEOH	LEBANON	165	2	S	5500	.	OIL
6	LEOH	LEBANON	165	3	S	6100	.	OIL
	MECP	CHILLICOTHE	141	68	S	.	.	UNK
1	OHEC	BURGER, R E	13	66	S	4401	.	BIT
2	OHEC	BURGER, R E	13	66	S	4712	.	BIT
3	OHEC	BURGER, R E	13	103	S	5003	.	BIT
4	OHEC	BURGER, R E	13	161	S	5503	.	BIT
5	OHEC	BURGER, R E	13	161	S	5506	.	BIT
1-4	OHEC	EAST PALESTINE	29	12	S	4799	.	BIT
6	OHEC	GORGE	153	48	S	4309	.	BIT
7	OHEC	GORGE	153	48	S	4812	.	BIT
1	OHEC	MAD RIVER	23	22	S	2707	.	BIT
2	OHEC	MAD RIVER	23	25	S	3811	.	BIT
3	OHEC	MAD RIVER	23	24	S	4902	.	BIT
1	OHEC	NILES	155	115	S	5401	.	BIT
2	OHEC	NILES	155	115	S	5406	.	BIT
1	OHEC	SAMMIS	81	188	S	5908	.	BIT
2	OHEC	SAMMIS	81	188	S	6007	.	BIT
3	OHEC	SAMMIS	81	193	S	6107	.	BIT
4	OHEC	SAMMIS	81	193	S	6211	.	BIT
5	OHEC	TORONTO	81	42	S	4010	.	BIT
6	OHEC	TORONTO	81	65	S	4908	.	BIT
7	OHEC	TORONTO	81	65	S	4911	.	BIT
2	OHPC	MUSKINGUM RIVER	115	220	S	5406	.	COL
3	OHPC	MUSKINGUM RIVER	115	238	S	5712	.	COL
4	OHPC	MUSKINGUM RIVER	115	238	S	5305	.	COL
1	OHVE	KYGER CREEK	53	217	S	5502	.	COL
2	OHVE	KYGER CREEK	53	217	S	5506	.	COL
3	OHVE	KYGER CREEK	53	217	S	5509	.	COL
4	OHVE	KYGER CREEK	53	217	S	5511	.	COL
5	OHVE	KYGER CREEK	53	217	S	5512	.	COL
	ORRV	NORTH VINE ST.	169	89	S	.	.	COL
	PIPG	BARBERTON	153	87	S	.	.	UNK
4	PIQU	PIQUA	109	8	S	4700	.	COL
5	PIQU	PIQUA	109	1	S	4700	.	COL
6	PIQU	PIQUA	109	13	S	5100	.	COL
7	PIQU	PIQUA	109	22	S	6100	.	COL
	RESC	YOUNGSTOWN	99	28	S	.	.	UNK
2	RMOH	READING	61	3	S	4600	.	UNK

(continued)

Table B.4. (continued)

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
4	RMOH	READING	61	6	S	5800	.	UNK
IC1	RMOH	READING	61	2	S	6500	.	UNK
IC2	RMOH	READING	61	2	S	6500	.	UNK
	SHBY	SHELBY	139	39	S	.	.	COL
2	SMML	SAINT MARYS	11	1	S	3900	.	OIL
4	SMML	SAINT MARYS	11	3	S	4600	.	COL
5	SMML	SAINT MARYS	11	6	S	5700	.	COL
	UNCA	MARIETTA	167	160	S	.	.	COL
	UNSS	YOUNGSTOWN	9	45	S	.	.	UNK
	YOST	CAMPBELL	99	49	S	.	7712	UNK
4	OHPC	PHILO	119	85	M	4110	7506	COL
5	OHPC	PHILO	119	85	M	4206	7505	COL
6	OHPC	PHILO	119	125	M	5708	7505	COL
1	OHPC	TIDD	81	105	M	4599	7610	COL
2	OHPC	TIDD	81	105	M	4899	7610	COL
1	OHPC	WOODCOCK	3	5	M	3800	7502	COL
2	OHPC	WOODCOCK	3	5	M	3800	7502	COL
3	OHPC	WOODCOCK	3	8	M	4100	7502	COL
4	OHPC	WOODCOCK	3	10	M	4700	7502	COL
5	OHPC	WOODCOCK	3	10	M	5000	7502	COL

Table B.5. CAPACITY REMOVALS, 1976 THROUGH 2000: PENNSYLVANIA

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
	BESC	JOHNSTOWN	21	75	S	.	.	UNK
1	DULC	ELRAMA	125	99	S	5206	.	COL
2	DULC	ELRAMA	125	105	S	5303	.	COL
3	DULC	ELRAMA	125	114	S	5411	.	COL
4	DULC	ELRAMA	125	176	S	6011	.	COL
1	DULC	PHILLIPS, F	3	74	S	4301	.	COL
2	DULC	PHILLIPS, F	3	83	S	4911	.	COL
3	DULC	PHILLIPS, F	3	82	S	5009	.	COL
4	DULC	PHILLIPS, F	3	148	S	5602	.	COL
	JOLS	ALIQUIPPA	7	47	S	.	.	UNK
	JOLS	PITTSBURG WORKS	3	70	S	.	.	UNK
H1	PEEC	PINEY	31	9	S	2406	.	WAT
H2	PEEC	PINEY	31	9	S	2407	.	WAT
H3	PEEC	PINEY	31	9	S	2802	.	WAT
3	PEEC	SEWARD	63	35	S	4112	.	MUL
4	PEEC	SEWARD	63	62	S	5005	9000	MUL
5	PEEC	SEWARD	63	156	S	5704	9700	COL
1	PEEC	SHAWVILLE	33	133	S	5408	9400	COL
2	PEEC	SHAWVILLE	33	133	S	5408	9400	COL
3	PEEC	SHAWVILLE	33	188	S	5912	.	COL
4	PEEC	SHAWVILLE	33	188	S	6004	.	COL
IC5	PEEC	SHAWVILLE	33	2	S	6312	.	OIL
IC6	PEEC	SHAWVILLE	33	2	S	6312	.	OIL
IC7	PEEC	SHAWVILLE	33	2	S	6312	.	OIL
1	PEPC	NEW CASTLE	73	47	S	3900	.	COL
2	PEPC	NEW CASTLE	73	50	S	4700	.	COL
3	PEPC	NEW CASTLE	73	115	S	5200	.	COL
4	PEPC	NEW CASTLE	73	134	S	5800	.	COL
5	PEPC	NEW CASTLE	73	160	S	6400	.	COL
D	PEPC	NEW CASTLE	73	6	S	.	.	FO2
1	SAJC	ST. JOSEPH	7	25	S	5902	.	COL
	SIKO	KOBUTA	7	35	S	.	.	UNK
	UNSS	CLAIRTON	3	49	S	.	.	UNK
	UNSS	CLAIRTON	3	40	S	.	.	UNK
	UNSS	EDGAR THOMSON	3	65	S	.	.	UNK
	UNSS	HOMESTEAD	3	68	S	.	.	UNK
1	WEPP	ARMSTRONG	5	180	S	5800	.	COL
2	WEPP	ARMSTRONG	5	180	S	5900	.	COL
1	WEPP	MITCHELL	125	89	S	4800	.	FO6
2	WEPP	MITCHELL	125	89	S	4900	.	FO6
3	WEPP	MITCHELL	125	291	S	6300	.	COL

Table B.6. CAPACITY REMOVALS, 1976 THROUGH 2000: WEST VIRGINIA

UNIT_ID	CO_INDEX	NAME	COUNTY	MWE	STATUS	DATE	RETIRE	FUEL
8	APPC	CABIN CREEK	39	85	S	4209	7710	COL
9	APPC	CABIN CREEK	39	85	S	4305	7710	COL
1	APPC	KANAWHA RIVER	39	220	S	5307	.	COL
2	APPC	KANAWHA RIVER	39	220	S	5312	.	COL
1	CEOC	SPORN, PHIL	53	153	S	5001	.	COL
2	CEOC	SPORN, PHIL	53	153	S	5007	.	COL
3	CEOC	SPORN, PHIL	53	153	S	5108	.	COL
4	CEOC	SPORN, PHIL	53	153	S	5202	.	COL
5	CEOC	SPORN, PHIL	53	496	S	6012	.	COL
	FOMA	SOUTH CHARLESTON	39	35	S	.	.	UNK
1	KVPO	LONDON	39	5	S	3601	.	WAT
2	KVPO	LONDON	39	5	S	3601	.	WAT
3	KVPO	LONDON	39	5	S	3601	.	WAT
1	KVPO	MARMET	39	5	S	3601	.	WAT
2	KVPO	MARMET	39	5	S	3601	.	WAT
3	KVPO	MARMET	39	5	S	3601	.	WAT
1	KVPO	WINFIELD	79	5	S	3801	.	WAT
2	KVPO	WINFIELD	79	5	S	3801	.	WAT
3	KVPO	WINFIELD	79	5	S	3801	.	WAT
2	MOPC	ALBRIGHT	77	76	S	5400	.	COL
3	MOPC	ALBRIGHT	77	140	S	5200	.	COL
1	POEC	ALBRIGHT	77	76	S	5200	.	COL
5	MOPC	RIVESVILLE	49	48	S	4300	.	COL
6	MOPC	RIVESVILLE	49	94	S	5100	.	COL
1	MOPC	WILLOW ISLAND	73	58	S	4900	.	COL
2	MOPC	WILLOW ISLAND	73	188	S	6000	.	COL
1	OHPC	KAMMER	51	238	S	5807	.	COL
2	OHPC	KAMMER	51	238	S	5811	.	COL
3	OHPC	KAMMER	51	238	S	5903	.	COL
	PIPG	MARTINSVILLE	103	120	S	.	.	UNK
	UNCA	ALLOY WORKS	19	102	S	.	.	WAT
	UNCA	ALLOY WORKS	19	123	S	.	.	UNK
1	VIEP	MT STORM	23	570	S	6500	.	COL
2	VIEP	MT STORM	23	570	S	6000	.	COL
1-4	WEPP	LAKE LYNN	61	52	S	.	.	WAT
	WESC	WEIRTON	29	109	S	.	.	UNK

APPENDIX C

AIR QUALITY DATA FOR ORBES COUNTIES, 1977

Table C.1. COUNTIES IN ILLINOIS, INDIANA, KENTUCKY, OHIO, PENNSYLVANIA, WEST VIRGINIA WITH VIOLATIONS OF NAAQS FOR SO_2 AND/OR LESS THAN THE FULL PSD INCREMENT AVAILABLE AT NADB MONITORS IN 1977

State and County	Number of Monitors Violating These Standards*			Number of Monitors with Less than the Full PSD Increment Available**		
	3 Hour	24 Hour	Annual	3 Hour	24 Hour	Annual
Illinois						
Cook	0	0	0	1	3	2†
Du Page	0	0	0	0	0	1†
Madison	0	1	1†	1	0	0
Peoria	0	0	0	1	1	0
Tazewell	0	1	0	1	0	0
Williamson	0	0	0	0	0	1
Indiana						
Floyd	0	0	1	1	1	0
Jefferson	0	0	0	1	0	0
Lake	0	2	0	1	0	3†
Marion	0	0	2†	0	1	1(1†)
Wayne	0	0	0	1	0	0
Kentucky						
Jefferson	0	0	3†	2	1	1(2†)
McCracken	0	0	0	3	2	0
Ohio						
Belmont	0	0	0	0	0	1†
Columbiana	0	0	1	1	1	1
Cuyahoga	1	2	2(2†)	3	2	4(1†)
Hamilton	0	0	0	0	1	1
Jefferson	0	0	2	0	1	2(2†)
Lake	0	1	1	1	0	1†
Lorain	0	1	1†	1	0	0
Lucas	0	2	0	3	1	1

(continued)

Table C.1. (continued)

State and County	Number of Monitors Violating These Standards*			Number of Monitors with Less than the Full PSD Increment Available**		
	3 Hour	24 Hour	Annual	3 Hour	24 Hour	Annual
Mahoning	0	0	1	0	0	2
Monroe	0	0	0	0	0	1
Montgomery	0	0	0	0	0	1†
Scioto	1	0	0	0	0	0
Stark	0	0	0	0	0	1
Summit	0	0	0	0	0	2(4†)
Pennsylvania						
Allegheny	0	2	5†	3	3	2†
Philadelphia	0	2	4†	2	3	2†
West Virginia						
Brooke	0	0	0	0	0	2
Hancock	0	0	2†	0	1	1(1†)
Marshall	0	0	0	0	0	1
Wood	0	0	0	0	0	1†

*The violations are defined as two observations > 1300μg/m^3 (3 hour), two observations > 365μg/m^3 (24 hour) or one observation $\geq$ 80μg/m^3 (annual).

**The working definition for "less than the full PSD increment available" in this table is the measured concentration to which the addition of the Class II PSD increment equals a violation of the standard. A monitor with a measured violation is not considered eligible.

†Less than four valid quarters of data were used for averaging the annual mean.

Source: U.S. Environmental Protection Agency. 1978. Air Quality Data - 1977 Annual Statistics Including Summaries with Reference to Standards. EPA - 450/2-78-040. Research Triangle Park, N.C. September.

Table C.2. COUNTIES IN ILLINOIS, INDIANA, KENTUCKY, OHIO, PENNSYLVANIA AND WEST VIRGINIA WITH VIOLATIONS OF NAAQS FOR TSP AND/OR LESS THAN THE FULL PSD INCREMENT AVAILABLE AT NADB MONITORS IN 1977

State & County	Number of Monitors Violating These Standards*				Number of Monitors with Less than the full PSD Increment Available**			
	24 Hour		Annual		24 Hour		Annual	
	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
Illinois								
Adams	0	1	0	1†	0	2	2	0
Bureau	0	1	0	0	0	0	1†	0
Champaign	0	0	0	1	0	1	0	0
Cook	10	40	20(3†)	32(6†)	3	12	8(1†)	12(1†)
De Kalb	1	4	1(2†)	2(3†)	0	1	1	0
Du Page	0	4	2	6	0	3	1	1
Effingham	0	0	0	0	0	1	1†	0
Jackson	0	0	1†	2†	0	0	0	0
Jefferson	0	1	0	1	0	0	0	0
Jo Daviess	0	1	0	1	1	0	0	0
Kane	0	0	0	0	0	1	0	1
Kankakee	0	1	0	1	0	0	0	0
Kendall	0	0	0	0	0	1	0	1†
Knox	0	1	0	1	0	0	0	0
Lake	0	1	0	1	0	3	1(1†)	3(1†)
La Salle	1	3	3†	3†	1	1	1	1†
McHenry	0	0	0	0	0	0	0	2
McLean	0	1	0	1	0	0	0	0
Macon	0	2	2	2	1	0	0	0
Madison	6	12	11(1†)	11(2†)	3	1	1	0
Massac	0	1	0	1†	0	0	0	0
Menard	0	0	0	0	0	1	1	0
Monroe	0	1	0	1	0	0	0	0
Peoria	0	2	2	4(1†)	0	2	0	0
Rock Island	0	3	2(1†)	4(2†)	0	3	1†	1
St. Clair	0	2	1(1†)	1(2†)	0	1	0	0
Sangamon	0	1	0	1	0	0	0	1†
Tazewell	0	1	2†	2†	0	1	0	0
Whiteside	0	0	0	1	0	1	0	1†
Will	0	6	3(1†)	7(3†)	0	4	2†	2(1†)
Williamson	0	0	0	0	0	1	0	1
Winnebago	0	0	0	0	0	2	1	0
Indiana								
Allen	0	0	0	0	0	0	1	1†
Bartholomew	0	0	0	1†	0	1	0	0
Clark	0	1	1	1	0	0	0	0
Delaware	0	0	0	0	0	0	0	2†
Dubois	0	0	0	1	0	1	0	0
Elkhart	0	0	0	0	0	0	0	1
Floyd	0	0	0	0	0	0	0	1
Howard	0	1	0	1	0	0	0	0
Grant	0	0	0	0	0	1	0	1
Jasper	2	2	1†	2†	0	1	0	0
Jefferson	0	0	0	0	0	0	0	1
Knox	0	0	0	1	0	1	0	0
Lake	2	14	3(6†)	7(15†)	1	6	1†	1(1†)
La Porte	0	0	0	0	0	0	0	2
Madison	0	0	0	0	0	3	0	1(3†)
Marion	0	7	3	10(2†)	0	7	1	4
Monroe	0	0	0	1	0	1	0	0
Porter	0	4	0	0	1	0	0	4†

(continued)

Table C.2. (continued)

State & County	Number of Monitors Violating These Standards*				Number of Monitors with Less than the full PSD Increment Available**			
	24 Hour		Annual		24 Hour		Annual	
	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
St. Joseph	0	0	0	4÷	0	4	1÷	1(4†)
Tippecanoe	0	0	0	0	0	0	1	0
Vanderburgh	0	1	0	2÷	0	1	1	2†
Vigo	0	3	4†	6†	0	2	0	0
Wayne	0	1	0	2	0	1	0	0
Kentucky								
Ballard	0	1	0	1÷	0	1	0	1
Barren	0	0	0	1	0	1	0	0
Bell	0	2	1(1÷)	1(1÷)	1	0	0	0
Boone	0	0	0	1(1÷)	0	3	1	2
Bourbon	0	0	0	0	0	1	0	1
Boyd	0	3	2	0	2	2	0	2(1÷)
Boyle	0	1	1	0	1	0	0	0
Bullitt	0	1	1÷	1÷	0	0	0	0
Caldwell	0	1	0	1	0	0	0	0
Calloway	0	0	0	0	0	0	0	1
Campbell	1	1	1÷	1(1÷)	0	2	0	1
Carlisle	0	0	0	0	0	0	0	1
Carroll	0	0	0	0	0	1	1	1
Carter	0	1	0	1÷	1	0	0	0
Christian	0	0	0	1	0	1	0	0
Clark	0	0	0	1÷	0	2	1	0
Daviess	1	4	4	5	1	2	0	1
Fayette	0	2	0	0	0	1	1	3
Floyd	0	0	0	1	0	1	0	0
Franklin	0	0	0	0	0	1	0	1
Fulton	0	0	0	1÷	0	1	0	0
Gallatin	0	0	0	0	0	1	0	1
Grayson	0	0	0	1	0	1	0	0
Greenup	0	1	0	0	0	0	1	0
Hancock	0	1	0	1	0	1	1	0
Hardin	0	0	0	0	0	2	1†	2
Harlan	0	1	1†	0	0	0	0	0
Harrison	0	0	0	1	0	1	0	0
Henderson	0	6	4	6	0	1	0	2
Hopkins	0	0	0	1	0	0	0	0
Jefferson	1	9	7(2÷)	12(2÷)	1	5	0	1(1÷)
Kenton	0	0	0	1	0	2	0	1
Laurel	0	1	0	1	0	0	0	0
Lawrence	0	1	0	1	0	0	0	0
Livingston	0	0	0	0	0	1	1÷	0
Logan	0	0	0	0	0	0	0	1
McCracken	0	5	1	3	0	3	2	5
Madison	0	1	1	1	0	0	0	1
Marshall	0	0	0	1÷	0	0	0	1
Mason	0	0	0	0	0	1	1	0
Meade	0	0	0	0	0	0	0	1
Muhlenburg	0	1	0	1	0	0	0	1÷
Nelson	0	0	0	0	0	1	0	1
Ohio	0	1	0	0	0	1	2	1
Oldham	0	0	0	0	0	1	0	2
Owen	0	0	0	0	0	1	1	0
Pendleton	0	0	0	0	0	0	0	1
Perry	1	1	1	1	0	0	0	0
Pike	0	1	1	1	0	0	0	0
Pulaski	0	0	0	0	1	1	1÷	0
Rowan	0	0	0	0	0	0	0	1
Shelby	0	0	0	0	0	1	1	0
Simpson	0	1	0	1	0	0	0	0
Todd	0	1	1	1	0	0	0	0
Trimble	0	0	0	0	1	2	0	2
Warren	0	0	0	1	0	2	0	1÷
Webster	0	0	0	1	0	1	0	0

(continued)

Table C.2. (continued)

State & County	Number of Monitors Violating These Standards*				Number of Monitors with Less than the full PSD Increment Available**			
	24 Hour		Annual		24 Hour		Annual	
	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
Whitley	0	1	1	0	0	0	0	0
Ohio								
Adams	0	0	0	0	0	1	1÷	2
Allen	1	2	0	2	0	0	0	0
Ashtabula	0	2	0	4	0	5	1	1(1÷)
Athens	0	0	0	0	0	1	1	0
Belmont	1	3	2	3	0	1	1	0
Brown	0	1	1(1÷)	1(2÷)	0	0	0	0
Butler	1	2	1	5	0	4	0	1
Carroll	0	2	0	1	0	0	0	2
Champaign	0	1	0	1	0	0	0	0
Clark	0	2	0	2	0	0	0	0
Clermont	0	1	1	2	0	3	1	2
Clinton	0	1	0	2	0	1	0	0
Columbiana	1	5	3	7	1	2	0	0
Coshocton	0	0	0	0	0	1	0	1
Cuyahoga	9	20	15(2÷)	21(2÷)	2	7	3	6(5÷)
Darke	0	0	1÷	1(1÷)	0	2	0	0
Defiance	2	5	1÷	1(3÷)	0	2	1÷	2÷
Delaware	0	1	0	1	0	0	0	0
Erie	0	1	0	2	0	1	0	0
Franklin	1	6	3	6(2÷)	0	5	1	3
Gallia	0	0	1÷	1÷	0	2	0	1
Geauga	0	1	0	1	0	2	0	2
Greene	0	1	0	1	0	2	1÷	1
Guernsey	0	0	0	0	0	1	0	1
Hamilton	0	7	8(1†)	19(1÷)	1	22	4	6(1÷)
Hancock	0	1	0	1	0	0	0	0
Harrison	0	1	0	1	0	2	1	1
Henry	0	4	1	2	0	2	0	1
Hocking	0	0	0	1÷	0	1	0	0
Jackson	0	1	0	1	0	0	0	0
Jefferson	5	10	7(1÷)	8(1÷)	0	1	1	0
Lake	1	9	3	8	1	4	1	4
Lawrence	4	7	3(1÷)	6(1÷)	0	1	1	1÷
Licking	0	0	0	0	0	1	0	1
Logan	0	1	1	1	1	0	0	0
Lorain	1	6	2	6	1	2	0	4(1÷)
Lucas	0	2	0	7(3÷)	0	10	0	4(1÷)
Mahoning	6	9	6(3÷)	6(3÷)	1	2	0	1
Marion	0	0	0	0	0	1	0	1
Medina	0	2	1÷	2(2÷)	0	2	0	0
Meigs	0	1	1	1	0	0	0	0
Miami	0	2	1	1(1÷)	0	1	1	0
Monroe	0	2	1	1	1	0	1	1
Montgomery	0	5	4(1÷)	6(3÷)	1	7	0	2(2÷)
Muskingum	0	0	0	1	0	2	1	0
Noble	0	1	0	1	0	0	0	0
Perry	0	0	0	0	0	1	0	1
Portage	0	0	0	2	0	2	0	0
Richland	0	7	1(2÷)	5(3÷)	0	2	1÷	2÷
Ross	0	1	0	1	0	2	0	3
Sandusky	5	11	5(1÷)	7(1÷)	3	1	0	5
Scioto	1	5	2(1÷)	6(1÷)	1	3	0	1(1÷)
Seneca	0	1	0	1	0	3	1	1(1÷)
Shelby	0	1	0	1†	0	1	1	0
Stark	0	11	5	11(1÷)	0	5	5	1
Summit	0	6	2	9(4÷)	0	9	2	1(1÷)
Trumbull	0	6	3	7	1	1	0	0
Tuscarawas	0	1	0	0	0	1	1(1†)	0
Union	0	2	0	2	0	1	0	1

(continued)

Table C.2. (continued)

State & County	Number of Monitors Violating These Standards*				Number of Monitors with Less than the full PSD Increment Available**			
	24 Hour		Annual		24 Hour		Annual	
	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
Warren	0	1	1	1	0	2	0	2
Washington	0	0	0	0	0	1	2	0
Wayne	0	1	0	1(2†)	0	3	0	1
Wood	0	0	0	0	0	2	0	3
Wyandot	2	3	2	3	0	0	0	0
Pennsylvania								
Allegheny	13	19	20†	23†	1	3	0	0
Beaver	3	8	8†	8†	2	0	0	0
Berks	0	2	1†	5†	0	3	0	2†
Blair	1	2	1†	2†	0	0	0	0
Bucks	0	0	0	0	0	0	0	3†
Cambria	4	5	5†	5†	0	0	0	1†
Chester	0	2	1†	2†	0	2	2†	0
Cumberland	0	0	0	1†	0	1	0	1†
Dauphin	0	1	1†	1†	1	1	1†	2†
Delaware	0	0	0	0	0	0	1†	2†
Erie	2	3	3†	3†	1	1	0	2†
Fayette	0	1	0	1†	0	0	0	0
Harrisburg	0	0	0	1†	0	1	0	0
Lackawanna	0	1	1†	2†	0	2	1†	0
Lancaster	0	2	1†	4†	0	2	1†	2†
Lawrence	2	2	2†	2†	0	0	0	0
Lenigh	0	0	0	0	0	0	0	2†
Luzerne	1	3	2†	4†	0	1	0	4
Lycoming	0	1	0	2†	0	1	0	0
Mercer	1	2	2†	2†	0	0	0	0
Montgomery	0	1	0	3†	1	2	0	1†
Northnampton	0	2	1†	4†	0	1	0	2†
Philadelphia	0	7	7†	10†	0	3	2†	1†
Washington	0	2	0	2†	0	2	1†	1†
Westmoreland	1	1	1†	1†	0	0	0	0
York	1	4	4†	5†	0	2	1†	1†
West Virginia								
Berkeley	0	1	0	0	0	0	0	0
Brooke	0	2	1	1	0	0	0	1
Cabell	0	1	0	1	0	1	0	0
Fayette	0	1	0	0	0	0	0	0
Hancock	0	3	0	2(1†)	1	0	0	0
Harrison	0	1	0	0	0	0	0	1
Kanawha	0	6	1	2	0	0	1	2
Lewis	0	1	0	0	1	0	0	1
Marion	1	2	1	1	0	0	0	0
Marshall	0	1	1	1	0	0	0	0
Mineral	0	0	0	0	0	2	0	0
Monongalia	0	0	0	0	0	1	0	0
Ohio	0	2	2†	4†	0	1	0	1
Putnam	0	0	0	0	0	1	0	1
Raleigh	0	1	0	0	1	0	0	0
Wood	0	1	0	0	0	0	0	2

*The violations are defined as two observations greater than 260 μg/m^3 (primary 24 hour), two observations greater than 150 μg/m^3 (secondary 24 hour), one observation equal to 75 μg/m^3 (primary annual) or one observation equal to 60 μg/m^3 (secondary annual). A measured violation of the primary standard is included as a violation of the secondary standard.

**The working definition given to "less than the full PSD increment available" is the measured concentration to which the addition of the Class II PSD increment equals a violation of the standards, e.g., $224 + 37 > 260$, $114 + 37 > 150$, $41 + 19 = 60$ and $56 + 19 = 75$. A monitor with a measured violation is not eligible for PSD increment consideration with the exception of a violation of the secondary 24 hour standard (> 150 μg/m^3) that leaves less than the full PSD increment toward the primary 24 hour standard, e.g., $224 \leq x \leq 260$.

†Less than four valid quarters of data were used for averaging the annual mean.

Source: U.S. Environmental Protection Agency. 1978. Air Quality Data - 1977 Annual Statistics Including Summaries with Reference to Standards. EPA-450/2-78-040. Research Triangle Park, N.C. September.

APPENDIX D

COUNTIES EXCLUDED AS SITES FOR COAL-FIRED SCENARIO UNIT ADDITIONS, BASE CASE ENVIRONMENTAL CONTROLS

Table D.1. COUNTIES EXCLUDED AS SITES FOR COAL-FIRED SCENARIO UNIT ADDITIONS, BASE CASE ENVIRONMENTAL CONTROLS

State	FIPS Code	Air Quality			Public Lands[c]
		Nonattainment[a]		PSD	
		TSP	SO_2	Class 1[b]	
Illinois					
Indiana	079		Marion		
	167		Vigo		
Kentucky	013	Bell			
	019	Boyd	Boyd		
	061			Edmonson	
	089		Greenup		
	111	Jefferson	Jefferson		Leslie
	131				
	145	McCracken	McCracken		
	147			McCreary	McCreary
	177	Muhlenberg	Muhlenberg		
	233		Webster		
Ohio	027	Clinton			
	091	Logan			
	105	Meigs			
	139	Richland			
	141	Ross			
Pennsylvania	003	Allegheny	Allegheny		
West Virginia	039	Kanawha			
	083			Randolph	
	093			Tucker	

[a] County designated nonattainment area, primary standards.

[b] County contains mandatory Class I area.

[c] All of county in public lands, actual ownership.

APPENDIX E

COUNTIES EXCLUDED AS SITES FOR COAL-FIRED SCENARIO UNIT ADDITIONS, STRICT ENVIRONMENTAL CONTROLS

Table E.1. COUNTIES EXCLUDED AS SITES FOR COAL-FIRED SCENARIO UNIT ADDITIONS, STRICT ENVIRONMENTAL CONTROLS

State	FIPS Code	Air Quality			Public Lands[c]
		Nonattainment[a]		PSD	
		TSP	SO_2	Class 1[b]	
Illinois	001	Adams			
	003				Alexander
	011	Bureau			
	069				Hardin
	081	Jefferson			
	091	Kankakee			
	095	Knox			
	099	LaSalle			
	113	McLean			
	115	Macon			
	119	Madison			
	127	Massac	Massac		
	129	Menard			
	133	Monroe			
	143	Peoria	Peoria		
	151	Pope			Pope
	155	Putnam			
	163	St. Clair			
	167	Sangamon			
	179	Tazewell	Tazewell		
	181				Union
	199	Williamson			

(continued)

Table E.1. (continued)

State	FIPS Code	Air Quality			Public Lands[c]
		Nonattainment[a]		PSD	
		TSP	SO_2	Class 1[b]	
Indiana	019	Clark			
	025				Crawford
	029	Dearborn			
	037	Dubois			
	067	Howard			
	097	Marion	Marion		
	101				Martin
	117				Orange
	123				Perry
	163	Vanderburgh			
	167	Vigo	Vigo		
	177	Wayne	Wayne		
Kentucky	013	Bell			
	019	Boyd	Boyd		
	029	Bullitt			
	037	Campbell			
	051				Clay
	059	Daviess	Daviess		
	061			Edmonson	
	065				Estill
	089		Greenup		
	101	Henderson	Henderson		
	109				Jackson
	111	Jefferson	Jefferson		
	127	Lawrence			
	129				Lee
	131				Leslie
	145	McCracken	McCracken		
	147			McCreary	McCreary
	151	Madison			
	157	Marshall			
	165				Menifee
	177	Muhlenberg	Muhlenberg		

(continued)

Table E.1. (continued)

State	FIPS Code	Air Quality			Public Lands[c]
		Nonattainment[a]		PSD	
		TSP	SO_2	Class 1[b]	
Kentucky	193	Perry			
	195	Pike			
	197				Powell
	205				Rowan
	233		Webster		
	235	Whitley	Whitley		
Ohio	003	Allen	Allen		
	009		Athens		
	013	Belmont			
	017	Butler			
	019	Carroll			
	021	Champaign			
	023	Clark			
	025	Clermont	Clermont		
	027	Clinton			
	029	Columbiana	Columbiana		
	031		Coshocton		
	037	Darke			
	049	Franklin	Franklin		
	053	Gallia	Gallia		
	057	Greene	Greene		
	061	Hamilton	Hamilton		
	079	Jackson			
	081	Jefferson	Jefferson		
	087	Lawrence			Lawrence
	091	Logan			
	099	Mahoning	Mahoning		
	101		Marion		
	103	Medina	Medina		
	105	Meigs			
	109	Miami			
	111	Monroe			
	113	Montgomery	Montgomery		
	115		Morgan		
	119	Muskingum	Muskingum		
	129		Pickaway		
	133	Portage			
	135	Preble			
	139	Richland			

(continued)

Table E.1. (continued)

State	FIPS Code	Air Quality			Public Lands[c]
		Nonattainment[a]		PSD	
		TSP	SO_2	Class 1[b]	
Ohio	141	Ross			
	145	Scioto			Scioto
	149	Shelby			
	151	Starke	Starke		
	153	Summit	Summit		
	155	Trumbull	Trumbull		
	157	Tuscarawas			
	163				Vinton
	167	Washington	Washington		
	169	Wayne			
	175	Wyandot			
Pennsylvania	003	Allegheny	Allegheny		
	005		Armstrong		
	007	Beaver			
	021	Cambria			
	051	Fayette	Fayette		
	053				Forest
	073	Lawrence			
	085	Mercer			
	125	Washington	Washington		
	129	Westmoreland	Westmoreland		
West Virginia	009	Brooke	Brooke		
	029	Hancock	Hancock		
	049	Marion			
	051	Marshall			
	069	Ohio			
	075				Pocahontas
	083			Randolph	Randolph
	093			Tucker	Tucker
	107	Wood			

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[a] County contains nonattainment area, primary and secondary standards.

[b] County contains mandatory Class I area.

[c] Majority of county in public lands; total area, including designated purchase area.

APPENDIX F

COUNTIES EXCLUDED AS SITES FOR NUCLEAR-FUELED SCENARIO UNIT ADDITIONS

Table F.1. COUNTIES EXCLUDED AS SITES FOR NUCLEAR-FUELED SCENARIO UNIT ADDITIONS

State	FIPS Code	Seismic Suitability[a]	Population Density[b]	Public Lands[c]
Illinois	003	Alexander		Alexander
	033	Crawford		
	047	Edwards		
	055	Franklin		
	059	Gallatin		
	065	Hamilton		
	069	Hardin		Hardin
	077	Jackson		
	081	Jefferson		
	083	Jersey		
	087	Johnson		
	101	Lawrence		
	119	Madison		
	127	Massac		
	133	Monroe		
	145	Perry		
	151	Pope		Pope
	153	Pulaski		
	157	Randolph		
	159	Richland		
	163	St. Clair		
	165	Saline		
	181	Union		Union
	185	Wabash		
	189	Washington		
	191	Wayne		
	193	White		
	199	Williamson		

(continued)

Table F.1. (continued)

State	FIPS Code	Seismic Suitability[a]	Population Density[b]	Public Lands[c]
Indiana	025			Crawford
	051	Gibson		
	083	Knox		
	097		Marion	
	101			Martin
	117			Orange
	123			Perry
	129	Posey		
	163	Vanderburgh	Vanderburgh	
Kentucky	007	Ballard		
	003	Calloway		
	037		Campbell	
	039	Carlisle		
	051			Clay
	055	Crittenden		
	065			Estill
	067		Fayette	
	075	Fulton		
	083	Graves		
	101	Henderson		
	105	Hickman		
	109			Jackson
	111		Jefferson	
	117		Kenton	
	131			Leslie
	139	Livingston		
	143	Lyon		
	145	McCracken		
	148			McCreary
	157	Marshall		
	165			Menifee
	197			Powell
	205			Rowan
	225	Union		
	233	Webster		
	235			Whitley
Ohio	017		Butler	
	049		Franklin	
	061		Hamilton	

(continued)

Table F.1. (continued)

State	FIPS Code	Seismic Suitability[a]	Population Density[b]	Public Lands[c]
	087			Lawrence
	099		Mahoning	
	113		Montgomery	
	145			Scioto
	151		Stark	
	153		Summit	
	163			Vinton
Pennsylvania	003		Allegheny	
	053			Forest
West Virginia	069		Ohio	
	075			Pocahontas
	083			Randolph
	093			Tucker

[a] County within relative seismic suitability zone III.

[b] County population density $\geq$ 500 persons per square mile.

[c] Majority of county in public lands; total area, including designated purchase area.

APPENDIX G

ECAR REGION SITE INVENTORY

The East Central Area Reliability (ECAR) council maintains an inventory of major thermal electric power plants that are located in the service areas of the council's member utilities. The inventory is based on the utilities reporting sites they own or have substantial holdings with options to buy.* Potential sites that companies may be evaluating for their suitability, or that have been indicated as potential alternate sites as required by a state siting agency or other authority, are not included. The ECAR site inventory includes all of the ORBES region except the Illinois state subregion, which is in the Mid-America Interpool Network (MAIN). No region site inventory is available for MAIN.

The ECAR region site inventory consists of a map of sites and a listing of selected site information. The site information includes the site name; the utility that reports the site; fuel types of generating units; and information about the size (in MWe) and number of units that are located at the site, or are under construction or planned. Those sites that can physically accomodate additional generation are also identified, although the inventory does not specify the magnitude of generation that could be added while meeting current air and water quality regulations and other certification requirements. These "expandable" sites that are located in the ORBES region are listed in Table C-1.

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*Correspondence form Mr. Owen A. Lentz, Executive Manager, ECAR, dated July 20, 1979 and August 20, 1979.

Table C.1. INVENTORY OF ELECTRIC UTILITY SITES IN THE ORBES PORTION OF INDIANA, KENTUCKY, OHIO, PENNSYLVANIA AND WEST VIRGINIA THAT ARE CAPABLE OF ACCOMODATING CAPACITY ADDITIONS

State Subregion	County	FIPS Code	Site Name	Company Acronym	Fuel Type				Size (MWe) and Number of Units		
					Coal	Oil	Nucl	Future	Present	Under Construction	Planned
INDIANA	Jasper	18073	R. M. Schahfer	NIPS	●				477(1)	682(2)	
	Jefferson	077	Marble Hill	PSI			●			2260(2)	7500
	Morgan	109	Paragon	IPL				●			
	Parke	121	Cayuga	PSI	●	●			1024(6)		
	Pike	125	Frank E. Ratts	HED	●				244(2)		
	Posey	129	A. B. Brown	SIGE	●					250(1)	
	Spencer	147	Rockport	AEP	●					2600(2)	
	Sullivan	153	Breed	AEP	●				400(1)		
	Switzerland	155	Patriot	IPL	●			●			
KENTUCKY	Boone	21015	East Bend	CG&E	●					1200(2)	
	Davies	059	Elmer Smith	OMU	●				399(2)		
	Hancock	091	Coleman	BIRI	●				455(3)		
	Henderson	101	Henderson	AEP				●			
	Lewis	135	St. Paul	AEP				●			
			Project 2602	AEP	●			●			
	Mason	161	H. L. Spurlock	EK	●				300(1)	500(1)	
	Pulaski	199	J. S. Cooper	EK	●				354(2)		
	Trimble	223	Trimble County	LG&E	●					495(1)	
			Unnamed	AEP				●			
	Webster	223	Reid/Henderson #2	BIRI	●	●			455(3)		
OHIO	Adams	39001	Killen	DPL	●					1200(2)	
			Sandy Springs	AEP				●			
	Athens	009	Poston	CSOE	●	●			250(5)	375(1)	
	Clermont	025	Zimmer	CG&E			●			807(1)	7300
	Jefferson	081	Rayland	CEI			●				
	Lawrence	087	Hanging Rock				●				
	Meigs	105	Great Bend	CSOE			●				
	Morgan	115	Muskingum Mine	AEP			●				

(continued)

Table G.1. (continued)

State Subregion	County	FIPS Code	Site Name	Company Acronym	Fuel Type				Size (MWe) and Number of Units		
					Coal	Oil	Nucl	Future	Present	Under Construction	Planned
PENNSYLVANIA	Armstrong	42005	Lower Armstrong	APS	●					1260(2)	
	Beaver	007	Mansfield	OE	●					825(1)	
WEST VIRGINIA	Mason	54053	Apple Grove	AEP				●			
			Mountaineer	AEP	●					2600(2)	
	Pleasants	073	Pleasants	APS	●					1252(2)	

SOURCE: ECAR Region Site Inventory, 1979.